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EDITOR ERIK LINDGREN

DIAGNOSIS

SEVENTH SYMPOSIUM
NEURORADIOLOGICUM
NEW YORK
21—25 September 1964
PART II

Pneumography — Ventriculography
Radioisotopes — Ultrasound — Thermography
Spine examinations — Myelography

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FROM THE RADIOLOGICAL AND NEUROSURGICAL SERVICES OF THE SYRACUSE MEMORIAL HOSPITAL AND THE DEPARTMENT OF RADIOLOGY AND THE NEUROSURGICAL DIVISION OF THE DEPARTMENT OF SURGERY OF THE STATE UNIVERSITY OF NEW YORK UPSTATE MEDICAL CENTER AT SYRACUSE, NEW YORK, U S A

HEMORRHAGE INTO CISTERN OF VELUM INTERPOSITUM IN INFANTS

by

ALFRED S BERNE and HERBERT LOURIE

There are many reports concerning intracranial hemorrhage in the immediate perinatal period (4 5) and in young children (6 7 8) However a review of the literature failed to disclose a report of the type of intracranial hemorrhage in young infants as will be recorded here Furthermore we have found no description of the pneumographic findings in subarachnoid hemorrhage in infancy similar to those to be described The clinical and radiologic features of these three cases of subarachnoid hemorrhage into the cistern of the velum interpositum in infants constitute a specific entity Analysis of these features adds information which appears to confirm the hypothetical etiologic relationship between perinatal intracranial hemorrhage and congenital communicating hydrocephalus (1) and incriminates fetal hypoxia as the precipitating factor

Case reports

Case 1 This 4 month-old girl was delivered as a vertex presentation after 16 hours of induced labor She appeared well until the day of admission to the hospital when she suddenly screamed several times became decerebrate and lapsed into coma Lumbar and ventricular

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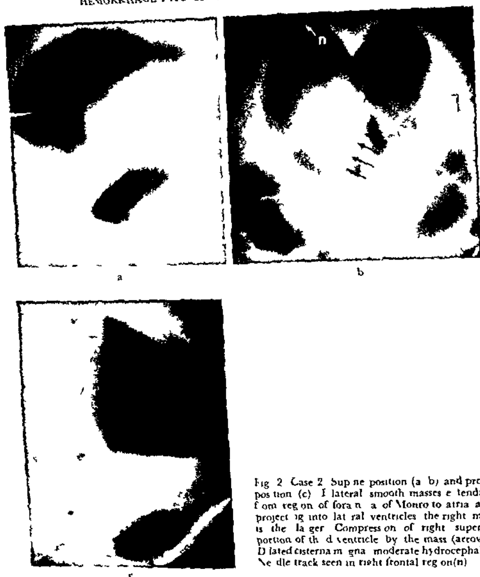


Fig 2 Case 2 Sup ne position (a b) and pror pos tion (c) I lateral smooth masses e tendir f om reg on of fora n a of Monro to atria ar project ng into lat ral ventricles the right ma is the la ger Compress on of right superi portion of th d ventricle by the mass (arrow D lated cisterna m gna moderate hydrocephali Ne dle track seen in right frontal reg on(n)

Ca e ? This 7 week-old boy was delivered as a vertex presentation Borderline cepha pelvic disproportion was present and the child was obviously hypoxic at birth (graded 5 the Apgar scale He made an apparent complete recovery and was doing well until one w before hospital admi s on when he vomited suddenly and became decerebrate Lum puncture at that time produced bloody spinal fluid and the infant improved considera over th next 6 days He was then transferred to this hospital for evaluation of an enlarg head



a



b



c

Fig 1 Case 1 Half axial and lateral projections supine position (a b) and prone position (c) Bilateral smoothly outlined masses projecting from floor into lateral ventricles the masses (→) extend from the foramina of Monro to the atria depression of roof of third ventricle (+→) minimal hydrocephalus

taps yielded grossly bloody fluid Serial cerebral angiography was performed and was normal Ventriculography was then done (Fig 1) The patient expired before therapy could be instituted

Autopsy revealed a solid clot which originated in the transverse cerebral fissure and had ruptured into the left lateral ventricle Extensive softening and hemorrhagic infarction of the left thalamus were present

This acute case with an overwhelming hemorrhage into the cavum velum interpositum and fatal intraventricular rupture is the prototype of the less severe subacute and chronic stages of this syndrome

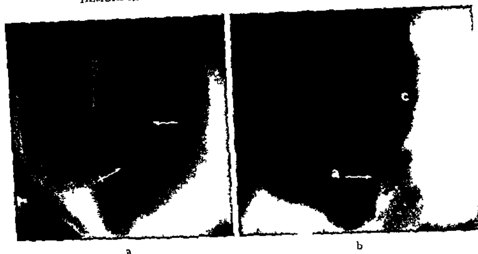


Fig 4 Case 3 Ventriculography supine position Smooth mass projecting into lateral ventricles much larger on the left (a→) compression of left side of roof of third ventricle (←→) cyst of cavum Verga (x c) moderate to marked hydrocephalus greater on left

The hydrocephalus was arrested for 6 weeks Then megacephaly was again obvious and encephalography and ventriculography were performed (Fig 5) The marked communicating hydrocephalus has been successfully treated with a ventriculojugular shunt

Discussion

The many similarities in these three cases constitute a distinct and well defined clinical and radiologic syndrome Each child was full term and the first born two were definitely hypoxic at birth and the third infant was born after 16 hours of induced labor Each patient was apparently healthy at the time of occurrence of a sudden intracranial hemorrhage The initial air study in each individual showed a mass in the cistern of the velum *interpositum* Later in the patients who survived as the mass disappeared a communicating hydrocephalus of increasing severity developed (Figs 1 to 5) Finally, in none of these patients was an obvious cause for hemorrhage found (*i e* vascular anomaly tumor blood dyscrasia etc)

The exhaustive study and review by HALLER NESBITT & ANDERSON (5) of perinatal *intracranial* hemorrhage is particularly informative These authors and others (2 3 4) stress that perinatal anoxia frequently causes overwhelming fatal hemorrhages *into the* area *of the* brain under discussion in this paper — the velum *interpositum and* the neighboring spaces of the transverse cerebral fissure (Fig 6) These hemorrhages are in contradistinction to the

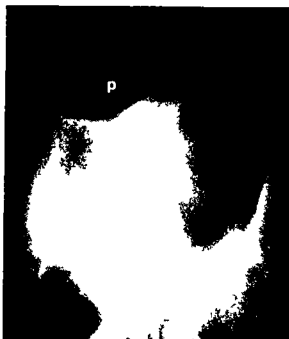


Fig 3 Case 2 Ventriculography supine position 2 months after examination in fig 2 No masses projecting into lateral ventricles the hydrocephalus is more marked a porencephalic cyst has developed at the site of the needle track (p)

Pink deeply xanthochromic fluid was obtained at ventricular tap performed for ventriculography 7 days after the acute episode (Fig 2) The head size stabilized and the baby again improved after ventricular tap

Six weeks later at the age of 14 weeks the baby was readmitted because of increasing head size Otherwise the infant s general state of health had been good Repeat ventriculograms were made (Fig 3) The mass in the cistern of the velum interpositum had disappeared the hydrocephalus was greater and a porencephalic cyst had developed at the site of the needle track made at the original ventriculography Intraventricular exploration through this cyst revealed only blood stained ependyma in the floor of the lateral ventricle no mass or vascular anomaly was found The baby expired postoperatively Permission for autopsy was refused

Case 3 This female infant was delivered as a breech presentation The delivery was complicated by a terminal abruptio placenta One loop of umbilical cord encircled the child s neck She was lethargic and nursed poorly for the first 3 days of life At age 5 days she appeared very well and was discharged from the hospital Thirty six hours later she became restless suddenly cried out in a strange manner became decerebrate and lapsed into coma Lumbar puncture produced bloody fluid Progressive improvement followed the tap and the baby was discharged from the hospital

At age 5 weeks an enlarged head was noted at a well baby check up and she was readmitted to the hospital Carotid angiography was unsuccessful on two occasions Ventriculograms were made (Fig 4) Cytologic study of the ventricular fluid which was deeply xanthochromic was reported as class V (malignant glioma) Because of this report the mass seen on ventriculography was explored surgically (HL) A cystic dilatation of the cavum velum interpositum and *hemosiderin stained* ependyma were found The abnormal cells originally reported were re examined and re classified as primitive ependymal cells

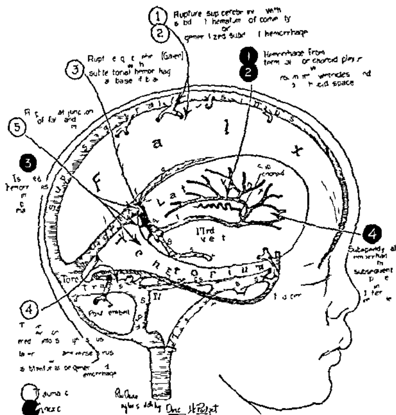


Fig 6 Schematic drawing to show frequent sites of injury and hemorrhage at birth The sites of anoxic les s a e ind cated by numbers encircled in black and traumatic lesions by numbers encircled in white (From HALLER NESBITT & ANDERSON Obstetrical and Gynecological Survey Vol 11 1956)

disease a severe communicating hydrocephalus develops as a result of the obliterative arachnoiditis which occurs secondary to the blood in the cistern of the velum interpositum and the adjoining ambient cisterns (1)

The radiologic diagnosis can be clearly established by its pneumographic features In the subacute or intermediate stage a mass conforming to the boundaries of the velum interpositum is demonstrated The mass extends anteriorly to the foramen of Monro and posteriorly to the atrial region and is smooth in outline It projects bilaterally into the bodies of the lateral ventricles and causes impression upon and depression of the roof of the third ventricle (Figs 1 2 and 4) The chronic or late stage is characterized by the usual radiographic features of a communicating non absorptive hydrocephalus



Fig 5 Case 3 Pneumography 4 months after the ventriculographic examination in fig 4 a) Erect lateral encephalogram Dilated interpeduncular cistern and gas rising into crural portion of ambient cistern (arrow) but not rising above level of tentorial notch b) Ventriculogram supine position The hydrocephalus has increased in severity A porencephalic cyst has developed at site of surgical exploration (x) the mass has disappeared

traumatic perinatal intracranial hemorrhages which occur in relation to the large dural sinuses

The similarity of the anatomical sites of hemorrhage in the cases reported here to those of the fatal anoxic hemorrhages reported in neonates, and the hypoxic circumstances surrounding our patients births appears to be more than coincidental If this hypothesis is accepted the evolution and pathogenesis of the syndrome described here become clear A newborn infant suffers a moderately severe but non fatal hypoxic episode at birth This results in hemorrhagic softening in the deep structures surrounding the cisterna velum interpositum and probable damage (9) to the walls of the many veins and venules in this region (10)

Subsequently, these weakened blood vessels, with the loss of their usual glial support, rupture into the cistern of the velum interpositum If the hemorrhage does not rupture into the ventricles the infant survives Pneumograms made at this stage of the disease will demonstrate a mass in the cistern of the velum interpositum as seen in Cases 2 and 3 (Figs 2 and 4) Later the mass will disappear as was demonstrated by the second pneumography performed in Cases 2 and 3 (Figs 3 and 5) At this time the late and final stage of the

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i e , dilated ventricles, dilated basal cisterns, and failure of gas to ascend above the tentorial notch to fill the supratentorial cisterns and cerebral sulci (1) (Figs 3 and 5)

Our experience would suggest that therapy during the acute and subacute stages of this syndrome be directed towards relieving intracranial pressure by ventricular and lumbar taps The clot in the transverse fissure will resolve and need not be attacked directly in these young infants Later if necessary, a shunt can be inserted to control the hydrocephalus

The evolution of this syndrome, from delayed hemorrhage into the midline cistern of the velum interpositum to that of classical "congenital" communicating hydrocephalus as it occurred in our cases, gives strong support to the theory that communicating hydrocephalus developing in other young infants is in fact related to perinatal hypoxic subarachnoid hemorrhage

Acknowledgements

The authors express their appreciation to Dr Arthur Ecker for permission to use Case 1 Case 2 was brought to our attention by Dr William Stewart and Case 3 by Dr Willet Bowen

SUMMARY

Three instances of hemorrhage into the cistern of the velum interpositum in young infants are described This delayed hemorrhage is related to perinatal hypoxia The acute stage may terminate fatally by intraventricular rupture of the hemorrhage The subacute stage is characterized by the presence of a mass occupying the cistern of the velum interpositum as shown by pneumography In the chronic stage pneumography will demonstrate an increasingly severe communicating hydrocephalus and disappearance of the mass from the cistern of the velum interpositum

ZUSAMMENFASSUNG

Es werden drei Beispiele von Blutungen in die Cisterna veli interpositi bei Kleinkindern beschrieben Diese verzögerte Blutung wird zu perinataler Hypoxie in Beziehung gesetzt Das akute Stadium kann infolge Ruptur der Blutung in die Ventrikel tötlich enden Das subakute Stadium ist durch eine Masse die die Cisterna veli interpositi ausfüllt wie mittels Pneumoencephalographie gezeigt werden konnte — gekennzeichnet Im chronischen Stadium zeigt die Pneumographie einen zunehmenden kommunizierenden Hydrozephalus und eine Verschwinden der Veränderung in der Cisterna veli interpositi

RÉSUMÉ

Présentation de trois cas d hémorragie dans la citerne de velum interpositum chez des nourrissons Cette hémorragie retardée est en rapport avec l hypoxie périnatale La phase aigue peut se terminer par la mort du fait de la rupture intraventriculaire de l hémorragie La phase subaigue est caractérisée par la présence d une masse occupant la citerne du velum interpositum et mise en évidence par pneumographie A la phase chronique la pneumographie montre une hydrocéphalie communicante qui va en s aggravant et la disparition de la masse qui occupait la citerne du velum interpositum

calcifications are also found it was of interest to find out whether these calcifications may shift in relation to the bony reference points of the skull base These reference points are used for the transfer of the target point from the pneumogram in the sitting position to the supine horizontal roentgenogram during operation by the methods mentioned above

2 The second question concerns the significance of possible shifts of intracranial structures due to the collection of extracerebral air during stereotaxic brain operations It was of interest to ascertain to what extent the identification of shifts resulting from gravitational influence is possible by observing the clinical effects of coagulations in the pallidum

Methods

Positional changes in sharply delineated pineal or habenular calcifications were chosen as indicators of relative shift in brain structures Localization of calcifications was determined in the brow up pneumogram by means of two landmarks appearing as bony irregularities in the regions of the dorsum sellae and planum sphenoidale From these two points (the endpoints of line C in *Fig 1*) lines were erected to form a triangle with the point of calcification (represented by F in Fig 1) The same triangle was then constructed in the subsequent conventional film taken in the supine horizontal position and revealing a large amount of extracerebral air (For comparison films were used in which the endpoints of line C coincided with an error of 0 10 mm or less) By measuring lines D and E (see Fig 1) localization of the calcified points could be compared and the distances between them measured The direction and the extent of shifts are indicated by arrows the real extent of which was multiplied by 30 to produce better clarity The several calcified points which actually differ in their localization in different skulls were indicated as the single point F The thickness of the amount of extracerebral air was measured as the maximal distance from the inner wall of the skull to the cortex

From the total material of 1 800 operated patients 14 cases were selected for analysis The small sample resulted from the fact that comparable films showing both calcifications and a significant amount of extracerebral air were infrequently found For control purposes 4 cases without extracerebral air were selected and the localization of calcifications in different head positions was determined in the manner described above

It was expected that positional changes of brain structures in patients with a large amount of extracerebral air might be reflected in the clinical effects of coagulations in the pallidum ince a somatotopic representation

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POSITIONAL CHANGES OF INTRACRANIAL STRUCTURES AFTER ENCEPHALOGRAPHY AND DURING STEREOTAXIC OPERATIONS

by

G Dieckmann, K Schmidt and J Prager

In stereotaxic brain operations at the Freiburger Neurochirurgische Universitätsklinik it is customary to perform the encephalography required for target point determination prior to the operation itself In 1 800 operations performed between 1952 and 1962, it was found that in 13 % of the cases some extracerebral air had collected before the skull was opened This air, resulting from encephalography prior to the stereotaxic procedure, later gathered in the rostral subarachnoid space Pneumograms to determine target points were obtained while the patient was in a sitting position During the stereotaxic operation the target point was transposed to the conventional skull films taken while the patient was in a supine position according to the localization method of Hassler & Riechert (1954) and after the technique of Riechert & Mundinger (1955) Two major questions arose

1 The first concerned the possibility of positional changes of intracranial structures due to gravitational influence, when an extracerebral intracranial amount of air exists In cases where sharply delineated pineal or habenular

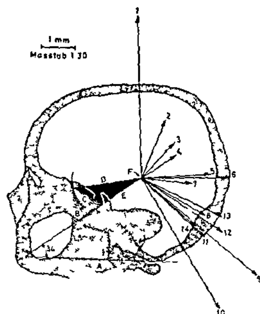


Fig 1 Direction and extent of positional change of pineal or habenular calcifications (F) associated with extracerebral air after encephalography Arrows indicate the direction of shift according to the localization of the extracerebral air 2—4 fronto-basal 6—7 frontal and 8—14 high frontal air Cases 1 and 5 did not shift according to expectation Triangle CDE was required to determine different positions of F in the compared films

8 9 10 11, 12, 13 and 14 in two anomalous cases shifts did not occur in the expected manner but rather in the direction indicated by arrows 1 and 5

It is evident that the direction of shift in these examples generally *corresponds* with the localization of extracerebral air signifying that the calcifications and thus the brain is shifted primarily in the direction of gravity

Four control cases without extracerebral air gave no indication of shift in calcifications

In the total number of pallidotomies for Parkinsonism 19 cases were noted in which no extracerebral air was seen during encephalography However skull films obtained 3 or 4 days later prior to the operation or after the opening of the dura revealed the presence of a significant amount of extracerebral air It was expected that especially in the transitional zone between arm and leg representation which is always entirely penetrated during operation shifts of the target area would be expressed in combined coagulation effects for arm and leg The clinical effects which indicate the pallidum coagulation are evidenced by an improvement of rigidity and to a lesser degree in tremor

Fig 2 shows a gross outline of the pallidum Above is the foramen of Monro with the base line The line labeled V indicates the direction of positional changes of intracranial calcifications The distance from the origin of line V to the upper angle of the black triangle is the average extent of shifts The line

of the areas for face and upper and lower extremities exists in the pallidum which follow the order of penetration by the coagulating electrode (HASSLER & RIECHERT 1958, MUNDINGER & POTTHOFF 1960) In the total operative material we observed 627 cases of pallidotomies Of these cases, 19 had a significant accumulation of extracerebral air, and 50 pallidotomies without air furnished comparative controls For determination of the pallidum internum we constructed a transparent model for superimposition on the film as a lateral projection view, as described by MUNDINGER & POTTHOFF (1960)

In cases with extracerebral air the direction of gravity and thus the direction of expected shifting was determined by a perpendicular line to the base of the air pockets, the mean direction of which was indicated by line V in Fig 2 and shows the mean direction of shift The base line was transposed from pneumograms to conventional skull films with the coagulating electrode in situ, by means of the bony reference points By constructing a perpendicular line from the tip of the electrode to the base line, and noting the distance from the intersection of the perpendicular with the base line to the interventricular foramen, the position of the tip of the electrode could be determined in each case The angle between the base line and the coagulating electrode was used for the construction of line W, which indicates the direction of electrode penetration According to the operation protocols the position of performed coagulations was marked on line W The clinically observed coagulation effect was then compared with the actual site of the coagulating electrode, and *the clinical effect was marked in the schematic pallidum by* means of symbols Because the coagulating electrode was introduced into the brain at an angle to the midsagittal plane, thereby causing the zone of penetration to appear foreshortened in the lateral sagittal view, it was necessary to correct for foreshortening by determining the cosine of the incident angle

Results

Fig 1 indicates the direction and extent of shifts in the position of pineal or habenular calcifications in 14 cases with an extracerebral amount of air, calculated from films taken both in the sitting and the supine positions Each arrow shows the relative extent and direction of shift in mm per case The average shift of calcifications for all 14 cases was 2 48 ± 1 08 mm The average maximum diameter of air pockets was 7 1 ± 2 15 mm

Relative to the direction of shift, the following is shown in Fig 1 Shifts resulting from air collection in the frontobasal extracerebral area are indicated by arrows 2, 3 and 4, frontal extracerebral air caused shifts in the direction of arrows 6 and 7, high frontal air accumulation corresponds to arrows

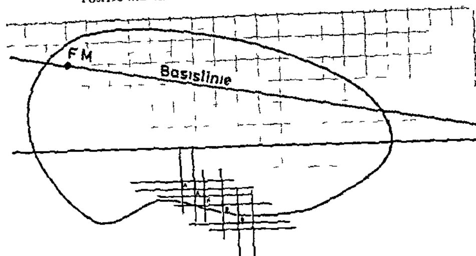


Fig 3 Sh ft g of target area indicated n segregated arm (A) leg (B) and comb ned (K) coagula t on effects n pall dotomies Rostral crosses of each letter denote target area in control cases caudal c os es of each letter target area in cases with extrace ebral a r

than in control cases This follows from the necessity in all operations to begin coagulations at the calculated target area and proceed normally though in reality (and unknown to the operator) the shifted target region is at a distance of a few millimeters beyond the normally predetermined target point Never theless the range of penetration in the control cases was 7 3 mm and in the others only 8 3 mm Such a small difference is explainable by the fact that in cases where the target area had shifted the entire arm and leg region was not actually penetrated in its total range, in order to avoid possible extension beyond the pallidum

Fig 3 contains drawn means and standard deviations of the above mentioned combined coagulation effects (arm and leg) labeled K and separate arm and leg effects labeled A and B respectively The mean coagulation effects for cases with air are always lying more caudally according to gravitational influence Crosses A rostral and caudal are situated relatively close together The distance between cro ses B rostral and caudal representing leg effects is greater than for crosses A representing arm effects but is still not as large as for combined effects K This is not surprising because the total range of arm and leg representation was not penetrated However the distance between leg effects B rostral and caudal could be expected to be even greater if the range of electrode penetration were not restricted in practice by the possibility of extending beyond the pallidum in cases with air While the interval between

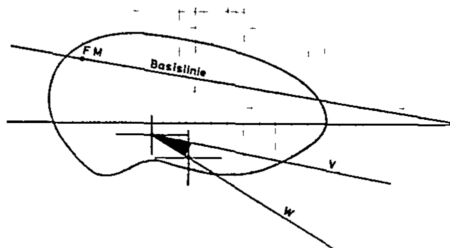


Fig 2 Shifting of target point in pallidotomies with frontal extracerebral air according to the maximal coagulation effect Rostral cross indicates mean and standard deviation of coagulation effect in control cases without extra cerebral air caudal cross the same in cases with frontal air Line V notes the direction of gravitational influence line W the direction of penetrating coag ulating electrode The black triangle is used to indicate the extent of expected shifting

labeled W is an empirical representation of the direction of electrode penetra tion during operation The perpendicular line from line V to line W defines the theoretical expectation of shift of the target point based on the measured average shifts of the calcifications mentioned before The intersection of caudal crossed lines on line W shows the area of maximal obtained coagulation effect, an average calculated from the point of maximal effect in each of the 19 cases with air The length of the crossed lines from the intersection depicts the standard deviation around the mean in this illustration for only the vertical and horizontal sagittal dimensions The intersection of the rostral crossed lines depicts the average point of maximal coagulation effect in 50 control cases without air Length of vertical and horizontal lines denotes the standard deviation of measurements as above

The difference of 2 7 mm between point of maximal effect for control cases shown rostrally, and the analogous point for cases with air shown caudally, is statistically significant at the 0 01 level, both for the ordinates and abscissas of the crossed lines (ordinates $p < 0.0005$ abscissas $p \leq 0.0025$) This suggests that the shift of the target area in patients with air is a real one The recorded shift in target area for cases with air is close to the theoretically expected target shift, estimated on the basis of positional changes of the calcifications

According to the positional change of the target for cases with air it would be expected that the range of electrode penetration would be greater

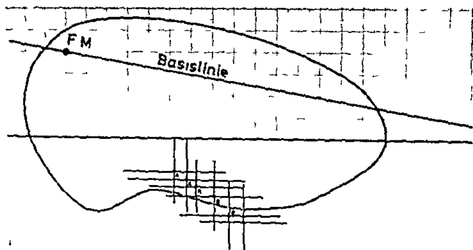


Fig 3 Shifting of target area indicated in segregated arm (A) leg (B) and combined (K) coagulation effects in pallidotomies Rostral crosses of each letter denote target area in control cases caudal crosses of each letter target area in cases with extracerebral air

than in control cases This follows from the necessity in all operations to begin coagulations at the calculated target area and proceed normally though in reality (and unknown to the operator) the shifted target region is at a distance of a few millimeters beyond the normally predetermined target point Nevertheless the range of penetration in the control cases was 7 3 mm and in the others only 8 3 mm Such a small difference is explainable by the fact that in cases where the target area had shifted the entire arm and leg region was not actually penetrated in its total range in order to avoid possible extension beyond the pallidum

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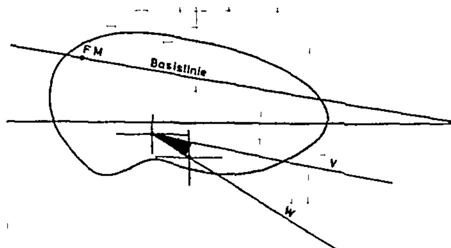


Fig. 2. Shifting of target point in pallidotomies with frontal extracerebral air according to the maximal coagulation effect. Rostral cross indicates mean and standard deviation of coagulation effect in control cases without extracerebral air, caudal cross the same in cases with frontal air. Line V notes the direction of gravitational influence, line W the direction of penetrating coagulating electrode. The black triangle is used to indicate the extent of expected shifting.

labeled W is an empirical representation of the direction of electrode penetration during operation. The perpendicular line from line V to line W defines the theoretical expectation of shift of the target point based on the measured *average shifts of the calcifications mentioned before. The intersection of caudal* crossed lines on line W shows the area of maximal obtained coagulation effect, an average calculated from the point of maximal effect in each of the 19 cases with air. The length of the crossed lines from the intersection depicts the standard deviation around the mean in this illustration for only the vertical and horizontal sagittal dimensions. The intersection of the rostral crossed lines depicts the average point of maximal coagulation effect in 50 control cases without air. Length of vertical and horizontal lines denotes the standard deviation of measurements as above.

The difference of 2.7 mm between point of maximal effect for control cases shown rostrally, and the analogous point for cases with air shown caudally, is statistically significant at the 0.01 level, both for the ordinates and abscissas of the crossed lines (ordinates $p \leq 0.0005$, abscissas $p \leq 0.0025$). This suggests *that the shift of the target area in patients with air is a real one.* The recorded shift in target area for cases with air is close to the theoretically expected target shift, estimated on the basis of positional changes of the calcifications.

According to the positional change of the target for cases with air it would be expected that the range of electrode penetration would be greater



Fig 5 Positional change of target point in a case of thalamotomy The target area was anticipated at the exit of the string electrode (—→) but was actually situated in the region of the tip of the string electrode (+→)

The decrease of the coagulating effect according to the penetration of the electrode in ventro-caudal direction in the control cases and the increase of the combined coagulating effects in the 19 patients with air according to the shift of the target point in direction of gravity is quite clear The action of gravity and the resulting shift of the target point is also evident though not so regular for leg effects We can notice a decrease according to the penetration of the electrode in control cases without air and an increase in cases with air Such correlations are not so obvious in cases of coagulation in the area of arm representation Since the zone of arm and leg representation were not penetrated in their entire length it is understandable that in these circumstances the effects would be more ambivalent

The practical consequences of these investigations are demonstrated in Fig 5 which depicts a case of thalamotomy with a large amount of frontal air The calculated target point was anticipated at the exit of the string electrode Due to the shift of the target point in the direction of gravity it was in fact localized significantly more caudally Only by penetrating with the string electrode in the direction of gravity was it possible to obtain a good coagulation effect

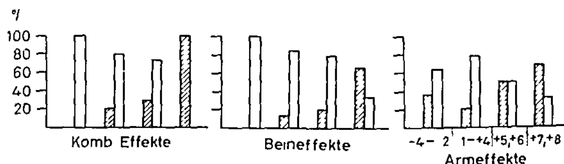


Fig. 4. Histogram showing the decrease of coagulation effect in control cases without air (white columns) and the increase of coagulation effect in cases with air (hatched columns) according to the position of coagulating electrode. Numbers on the abscissa indicate the position of the coagulating electrode with regard to the calculated target point. Negative numbers mean positions rostral from the target point, positive numbers mean ventro-caudal positions from the target point.

specific effects for control cases and cases with air is not so impressive as for combined effects, the general trend of target point shift in the direction of gravity is clear, and congruent with theoretical expectation. It would also appear that the leg effects as well as combined effects are situated outside of the schematic pallidum. Moreover, the distribution of effects in this figure based on the most impressive clinical observations during operations seems to correspond to the localization and extent of the ansa lenticularis, from which maximal coagulating effects can be obtained as is well known.

Isolated and combined effects are further elaborated in the histograms of Fig. 4. On the abscissa is shown the distance in mm from the tip of the coagulating electrode to the calculated target point in the zone of penetration. Numbers with negative signs signify withdrawal of the electrode from the target point in a dorso-rostral direction. Numbers with positive signs signify extention of the electrode beyond the target point in a ventro-caudal direction. The distances are divided into four groups. White columns represent the control cases, and the hatched columns patients with extracerebral air. The total number of operated patients in which coagulations were performed according to the area marked on the abscissa is taken as 100 %. The ordinates represent the percentage of cases per group with air or without air in which effects were observed in arm, leg, or combined categories.

Regarding the category of combined effects, in the range of − 4 to — 2 we observe only cases without extracerebral air. From the range of — 1 to + 4 we begin to see an occurrence of patients with air, but control cases are still more prevalent. More patients with air caps appear in the third group + 5 to + 6, while for the extremely ventro-caudally situated coagulations only cases with extracerebral air are observed.

ZUSAMMENFASSUNG

Intracranielle extracerebrale Luftansammlungen von mehr als 4 mm Dicke bedingen eine Verschiebung einer verkalkten Glandula pinealis oder Commissura habenularum wie Vergleiche zwischen im Sitzen angefertigten Encephalogrammen und später im Liegen aufgenommenen Leerbildern zeigen Die Verschiebung beträgt bei einer Luftsichelstärke von 7 4 ± 2 15 mm im Mittel 2 48 ± 1 08 mm Pallidotomie Effekte bei Patienten mit und ohne frontalen Luftkappen sprechen für eine Verschiebung stereotaktischer Zielgebiete um etwa 2 7 mm in Richtung der Schwerkraft bei Fällen mit extracerebraler Luftansammlung

RÉSUMÉ

La présence d air dans le crane en dehors du cerveau en une couche de plus de 4 mm d épaisseur cause un déplacement des calcifications pinéale ou habénulaires dans le sens de la pesanteur apprécié par comparaison de radiographies simples prises en décubitus et de pneumographies en position assise Les calcifications se déplacent de 2 48 ± 1 08 mm quand l air extracérebral est épais de 7 4 ± 2 15 mm Les auteurs ont comparé les effets des coagulations chez des malades avec et sans air extracérébral Les régions-cibles donnant les effets cliniques associés du membre supérieur et du membre inférieur ont été déplacées dans le sens de la pesanteur d environ 2 7 mm dans les cas avec air

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Discussion

FRORIEP (1897) has demonstrated the possibility of brain shifting in the post mortem state due to loss of cerebrospinal fluid. Similar shifts were expected with evacuation of the subarachnoid fluid in stereotaxic operations after opening the dura mater, especially in cases with cortical atrophy of marked degree. In these circumstances we observed a change in the relation of intracerebral points to bony reference points. The significance for stereotaxic operations with previous pneumography seems to be evident. Nevertheless, during encephalography with replacement of the subarachnoid fluid by air, VAN BUREN & MACCUBBIN (1962) did not find a significant positional change of intracerebral landmarks as in the 14 cases described above. They noted an average shift of 0.7 mm with gravity and of 0.5 mm against gravity unrelated to the thickness of extracerebral air. An explanation of this discrepancy in results appears difficult. The possibility of errors in measurements and technique as described by VAN BUREN & MACCUBBIN we believe were avoided by us. The important question of the influence of head rotation along the vertical axis investigated by these authors in a model experiment perhaps is not of significance here, because our intracerebral landmarks lie so near the region of the vertical rotation axis of the head. On the other hand, the bony reference points used in our study are nearer this vertical axis than the glabella used by VAN BUREN & MACCUBBIN in their pneumographic studies. Perhaps it is a question of different filling techniques in encephalography, although our cases did not show a subdural filling. However, we can note a correspondence between the results of pneumographic studies as shown in Fig. 1 and the findings during stereotaxic operations in cases with subdural air.

The problems mentioned above should be considered only in a descriptive and statistical manner. Anatomical points of view concerning the numerous possibilities of variation with which the stereotaxic operator is often confronted remain deliberately unmentioned. The question of the somato-topic differentiation of the pallidum, not yet acknowledged by all authors, is not discussed here, but it would seem that such a differentiation is confirmed by the above investigation.

SUMMARY

Intracranial extracerebral air more than 4 mm wide is associated with shifts of the pineal or habenular calcifications in the direction of gravity when supine conventional roentgenograms are compared to upright pneumograms. Calcifications shifted 2.48 ± 1.08 mm with a thickness of extracerebral air of 7.4 ± 2.15 mm. Coagulation effects in patients with and without extracerebral air were compared. Target areas for clinically observed combined arm and leg effects shifted approximately 2.7 mm in the direction of gravity for cases with air.

Table

Analysis of the radiological changes observed during encephalography

Case No	Cavum septi pellucidi	Brain atrophy			
		Ventricular enlargement	Cortical atrophy	Cerebellar atrophy	Dilatation of cistern of lamina terminalis
1	×	×		×	
2		×	×		
3	×	×			
4					
5	×	×		×	
6	×		×		
7	×	×			
8					
9		×			
10					
11					
12		×			
13				×	
14	×	×			
15	×	×			×
16					

Cavum septi pellucidi Changes in the septum pellucidum are of particular interest (Fig 1) The septum is a thin triangular shaped membranous partition separating the lateral ventricles and consisting of two laminae It is attached above to the corpus callosum below to the anterior part of the fornix posteriorly and the reflected portion of the corpus callosum anteriorly

Various abnormalities of the septum have been described in anatomical and autopsy studies Perforation of the septum is well recognised and DANDY (1931) considered many such perforations to be acquired Three types of cavum septi pellucidi have been recorded (VAN WEGENEN & AIRD 1943) the non communicating type the communicating type with openings into the lateral or third ventricles and the type associated with internal hydrocephalus

In this series of cases in order to demonstrate the integrity of the septum pellucidum or the walls of a cavum septi pellucidi an antero posterior film using a horizontal beam with the patient lying on his side was taken Antero posterior tomography was also carried out in some of the patients The antero posterior horizontal view will in normal circumstances demonstrate some air trapped in the lowermost ventricle whereas in a perforated septum air will

FROM THE DEPARTMENTS OF NEURORADIOLOGY AND NEUROLOGY, MANCHESTER ROYAL INFIRMARY, MANCHESTER, ENGLAND

PNEUMOENCEPHALOGRAPHIC CHANGES IN BOXERS

by

IAN ISHERWOOD, C MAWDSLEY and F R FERGUSON

In recent years interest has been directed towards neurological disease in boxers Associated encephalographic changes were first observed by SPILLANE (1962) in a study of five boxers, four of whom had abnormal encephalograms We have had the opportunity to carry out encephalographic studies in a further sixteen ex boxers, all of whom had evidence of neurological disease The clinical features of some of these patients have been the subject of discussion in a previous communication by MAWDSLEY & FERGUSON (1963)

The main purpose of this paper is to classify the radiological changes which have been observed in association with this type of traumatic encephalopathy and to assess their significance and diagnostic value

Results

Of the sixteen patients in the present study, three had normal encephalograms whilst the remaining thirteen had a variety of abnormalities (see Table) The abnormal findings were (1) cavum septi pellucidi in 9 cases (2) evidence of brain atrophy (generalised ventricular enlargement in 11 cases cerebral cortical atrophy in 3 cases, cerebellar atrophy in 4 cases) (3) enlargement of the cistern of the lamina terminalis in 4 cases

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2		x	x		
3	x				
4					
5		x		x	
6	x		x		
7		x			
8					
9		x			
10		x			
11					
12				x	
13				x	x
14		x			
15		x			
16		x			

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Fig 4 Oblique view of autopsy specimen demonstrating multiple perforations in walls of cavum septi pellucidi

In the present series of sixteen cases nine patients had evidence of a communicating cavum septi pellucidi an incidence of 56 %. If the cases described by SPILLANE (1962) are considered the recorded incidence of abnormal communication between the lateral ventricles with or without a cavum in boxers is 13 out of 21 patients i e , 62 %

The natural incidence of a communicating cavum septi pellucidi has never previously been determined accurately though THIEFFREY et coll (1958) suggested 1 %. In the last 300 unselected encephalographies carried out in the Manchester Royal Infirmary three cases have been recorded, giving a similar incidence

Tomography demonstrated the walls of the cavum to be intact anteriorly but to have multiple perforations behind the foramina of Monro increasing in number posteriorly (Fig 3) These observations have been confirmed by an autopsy study of the brain of an ex boxer where it was noted that the fenestrations increased posteriorly to a point where only a few residual strands of the lamellae remained (Fig 4) A free communication between the posterior ends of the lateral ventricles was thus allowed

It is of interest that in the three cases of cavum septi pellucidi observed incidentally none of whom were ex boxers two showed evidence of communication with one lateral ventricle only and in the third patient the cavum septi pellucidi communicated with a well developed cavum vergae These variations have not been recorded in any of the boxers in the series



Fig 1 A p film The cavum septi pellucidi is visible ventricular enlargement

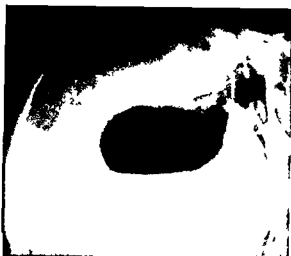


Fig 2 A p film right lateral decubitus position All air has risen to upper ventricle due to septal perforation



Fig 3 Tomography a) Walls of cavum septi pellucidi intact anteriorly b) and c) Multiple perforations in walls of cavum septi pellucidi from foramina of Monro posteriorly

rise to the upper ventricle (Fig 2) Some air may of course spill through the foramina of Monro but in a series of over 300 unselected encephalograms where this procedure was employed, this only occurred in 4 cases all of whom had large ventricles Where linear tomography during encephalography was carried out it was found essential to employ transverse movement of the tube in relation to the patient s head in order to avoid linear blur of the septal structures under investigation



Fig 8 Tomography in mid sagittal plane Dilatation of cistern of lamina terminalis cavum septi pellucidi visible

recorded from 20 % by SCHWIDDE (1952) to 60 % by SCHUNK (1963) where the average separation of the leaves has been 3 mm

It is suggested that dilatation of the cavum and perforation of its walls precedes the occasional disappearance of the septum as observed in one patient described by SPILLANE (1962) and that this disappearance occurs first posteriorly (Fig 5) None of the boxers without a communicating cavum however showed any radiological evidence of widening of the septum

Evidence of brain atrophy Generalised ventricular enlargement In ten of the patients ventricular enlargement was observed This was recorded initially as a subjective impression A further review employing a variety of generally accepted methods of measurement (ENGESET 1964) to assess ventricular size has confirmed these findings

Cerebral cortical atrophy In three patients the cerebral sulci were widened

Cerebellar atrophy In four patients the subarachnoid space around the cerebellum was markedly increased in size (Fig 6)

The radiological changes indicating brain atrophy i e ventricular enlargement cortical and cerebellar atrophy have been observed after head injuries (FRIEDMAN 1932 JACKSON & FLEMINGER 1946 TROLAND et coll 1946)

Direct brain damage due to mechanical acceleration and rotation strains together with localised petechial haemorrhages gives rise to glial replacement



Fig 5 P a film Complete disappearance of septum posteriorly



Fig 6 Dilatation of subarachnoid space around cerebellum in an ex boxer



a



b

Fig 7 Dilatation of cistern of lamina terminalis a) Patient erect Fluid level evident b) Brow up

There seems no doubt therefore, that the changes observed in the septum pellucidum in boxers are a significant feature and the role of trauma in their production must be considered proven The changes may be produced by a sudden elevation in ventricular pressure with rupture of the floor or walls of the potential cavum septi pellucidi Later pressure rises might cause dilatation of the cavum and perforation of its walls

A potential space between the leaves of the septum pellucidum is normally present and the incidence of a non communicating cavum has been variously

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Such changes may result in local atrophy It is suggested that there is a correlation between the degree and distribution of atrophy demonstrated radiologically and the severity and type of neurological affection evinced clinically

Enlargement of the cistern of the lamina terminalis In four of the patients an unusual dilatation of the cistern of the lamina terminalis was observed (Fig 7), a phenomenon not previously recorded Three of the patients exhibiting this dilatation also had a cavum septi pellucidi Tomography in the mid sagittal plane demonstrated the dilated cistern clearly, together with its relationship to the cavum septi pellucidi (Fig 8) The mechanism of production of this dilatation is uncertain, but the repetitive transient elevation of intracranial pressure brought about by traumatic deformation of the skull may be responsible It is possible that this mechanism may also result in a rupture of the floor or walls of the cavum septi pellucidi

Conclusions

In the investigation of neurological disorder in boxers, the demonstration of a communicating cavum septi pellucidi, particularly in association with ventricular enlargement, cortical or cerebellar atrophy, or enlargement of the cistern of the lamina terminalis, is very strong evidence in favour of a traumatic origin of the disease

SUMMARY

The radiologic changes observed in 16 ex boxers have been described with particular reference to tomography and encephalography and their significance and diagnostic value as compared with a normal control group A possible mechanism for the production of some of these changes is suggested

ZUSAMMENFASSUNG

Die an 16 Exboxern beobachteten rontgenologischen Veranderungen werden mit besonderer Berucksichtigung von Tomographie und Encephalographie beschrieben Ihre Bedeutung und ihr diagnostischer Wert wird mit den Befunden einer normalen Kontrollgruppe verglichen Ein Mechanismus der fur die Entstehung einiger dieser Schaden in Betracht kommt wird vermutet

RESUMÉ

Les auteurs décrivent les signes radiologiques observés chez 16 anciens boxeurs en particulier les signes tomographiques et encéphalographiques et examinent leur importance et leur valeur diagnostique en les comparant a un groupe témoin normal Les auteurs proposent un mécanisme possible de la production de certains de ces signes

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FROM THE RADIOLOGICAL AND NEUROSURGICAL SERVICES, CENTRAL AERONAUTICAL HOSPITAL, BUENOS AIRES, ARGENTINE

A NEW DIAGNOSTIC METHOD BY TRANS-OVAL CISTERNOGRAPHY

by

ABEL P JIMÉNEZ, JULIO LYONNET and FERNANDO SILVA

The radiological diagnosis of cerebello pontine angle tumours is usually established by the classic methods conventional films of the skull, angiography, and encephalography Sometimes, however, there are problems which make the diagnosis difficult For these cases we are using a new method with very good results

Basically, it consists in putting a positive contrast material into the trigeminal cistern, which lies within the cavum meckli and freely communicates posteriorly with the basal cisterns (Fig 1)

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F g 1 The posterior fossa viewed from above aft r ci on and separation of the tentorium Meckel s ca ty at row



Fig 2 Anatomical specimen showing the needle track and its landmarks



F g 3 No m l c sternog aphy



F g 4 Subarachno d cyst Absence of fill ng of th cir umpeduncular ci t rn in the posterior part

FROM THE RADIOLOGICAL AND NEUROSURGICAL SERVICES, CENTRAL AERONAUTICAL HOSPITAL, BUENOS AIRES, ARGENTINE

A NEW DIAGNOSTIC METHOD BY TRANS OVAL CISTERNOGRAPHY

by

ABEL P JIMENEZ, JULIO LYONNET and FERNANDO SILVA

The radiological diagnosis of cerebello pontine angle tumours is usually established by the classic methods conventional films of the skull, angiography, and encephalography Sometimes, however, there are problems which make the diagnosis difficult For these cases we are using a new method with very good results

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F g 1 The posterior fossa viewed f om above fter i c s on and separat on of the tento ium Meckel s cavity at *arrow*



Fig 2 Anatomical specimen showing the needle track and its landmarks



F g 3 Normal ci t rnog aphy



Fig 4 *Subarachnoid* cyst Absence of f ll ng of tl e c rcumpedu cula ister i in th posterior part



Fig 5 Glioma of the pons in a child As in fig 4 stop in the circumpeduncular cistern the contrast medium does not go down to the cistern of the vein of Galen

With an approximately 15 cm long spinal puncture needle, we pierce the skin of the cheek, immediately below the malar bone and immediately inside the mandibular ramus The needle is placed perpendicular to the drawn line Viewed laterally, the needle points toward the zygomatic tubercle, and looking frontally it points toward the infraorbital foramen The end of the needle thus reaches the foramen ovale When passing through it we feel the same sensation as when we pierce the dura mater in a lumbar puncture At this stage, we advance the needle one centimeter and we then pass into the trigeminal cistern We can prove this in two ways first when withdrawing the stilette a few drops of cerebrospinal fluid will emerge, second, by taking an antero posterior roentgenogram of the skull with the beam parallel to the orbito meatal line the tip of the needle will be at the level of the petrous ridge Having these proofs (and with possible errors corrected), we inject 1 5 or 2 ml of an iodized oil The medium being heavier than the C S F , it will go through the only possible way, on account of the position of the patient's head, and the substance will fall into the adjoining basal cisterns Before the needle is removed we inject corticosteroids through it, as in myelography when we use the same contrast medium Then we obtain the roentgenograms The first, submento vertex, is the main one (Fig 3) It shows a complete image of the cisterns, as seen in Fig 1 We also take a lateral and a half axial view Any possible space occupying lesion within the cisterns or their vicinity, of sufficient size, will alter the anatomical sketch and this alteration is clearly shown at the cisternography



Fig 6 N u noma of the t igeminus Tumor completely surrounded by the pos tive contrast

The early roentgen sign of abnormality is absence of filling of the circumpe duncular cistern (Figs 4 and 5) The contrast medium does not pass down to the vein of Galen cistern as it normally does When the tumor lies on the wider part of the cisterns, it is sharply outlined showing a lacunar image completely surrounded by the positive contrast In this case the tumor is well delineated and localized (Fig 6)

The technique is much easier than it seems from the description We have experienced no significant complications There is the possibility of arachnoid irritation as a reaction to the iodized oil Future improvement of the contrast media will lessen thi risk Trans-oval cisternography does not alter the ten sional equilibrium between the endocranical and spinal fluid and can be used without hazard with high intracranial pressure We have tried to change the positive contrast for air but we have not been able to obtain satisfactory results

We see other possibilities for this new method such as implantation of radioactive substances for diagnostic and therapeutic purposes

SUMMARY

We present a new diagnostic method especially useful for cerebello-pontine angle tumours The technical aspects of the procedure are described and normal and pathological cases are shown

ZUSAMMENFASSUNG

Eine neue diagnostische Methode wird beschrieben die besonders fur die Diagnose von Bruckenwinkeltumoren von Nutzen ist Normale und pathologische Falle werden gezeigt

RÉSUMÉ

Présentation d une nouvelle méthode diagnostique particulièrement utile pour les tumeurs de l angle ponto-cérébelleux Description de la technique et présentation de cas normaux et pathologiques

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FROM THE DEPARTMENTS OF RADIOLOGY AT BOSTON VETERANS ADMINISTRATION HOSPITAL AND PETER BENT BRIGHAM HOSPITAL AND THE DEPARTMENTS OF NEUROLOGY AT BOSTON VETERANS ADMINISTRATION HOSPITAL AND TUFTS UNIVERSITY SCHOOL OF MEDICINE BOSTON U S A

ENCEPHALOGRAPHY IN THE DIAGNOSIS OF CEREBELLAR ATROPHY

by

MARJORIE LEMAY and ARTUR ABRAMOWICZ

Most of the published articles describing the encephalographic findings in atrophic lesions of the cerebellum have been case reports of patients with the diagnosis established clinically or pathologically (EPSTEIN & DAVIDOFF 1946 ELLERMAN 1943 MURPHY & ARANA 1947 UZMAN 1948) The cerebellar folia are usually not well demonstrated in routine air studies and the radiologic diagnosis of atrophy often has been made upon indirect evidence derived from demonstration of a large cisterna magna or fourth ventricle This is analogous to the indirect evidence frequently used in the radiologic diagnosis of cerebral atrophy yet it is being recognized that enlargement of the lateral ventricles does not necessarily denote cerebral cortical atrophy and that there is often little correlation between the volume of the ventricular system and clinical symptomatology (HAMMERBERG & FOG 1959 STALLWORTHY & SAVAGE 1955)

The present work was carried out on a series of patients whose cerebellar sulci were well demonstrated at encephalography in order to study the relationship between the radiologic and neurologic diagnosis of atrophy The size of the fourth ventricle and cisterna magna were measured and contrasted



Fig 1 Normal cerebellar sulci

with the width of the cerebellar sulci and the data thus obtained correlated with the clinical symptomatology presented by the patients

Material and Method A total of 700 consecutive encephalographic examinations were reviewed In 72 of these cases the cerebellar sulci were well outlined Some of the patients were studied by the technique described by THIBAUT, WACKENHEIM & VROUSOS (1959) in which it is usually possible to demonstrate the cerebellar sulci without using large amounts of air In none of the cases was an attempt made to drain the spinal fluid completely and replace it with air In most of the patients 40 to 60 ml of air were injected and slightly less fluid removed

The 72 cases were divided into three groups a normal group in which the cerebellar folia were separated from each other by not more, and usually less, than 2 mm wide air spaces (Fig 1), a group in whom a mild to moderate degree of cerebellar atrophy was judged to be present on the basis of 2 to 4 mm wide air spaces separating the folia (Fig 2) and a group classified as marked atrophy, with separation of the cerebellar folia by air spaces wider than 4 mm (Fig 3)

The clinical records of the 72 cases were reviewed independently without reference to the encephalographic findings and a note was made of pertinent clinical history and neurologic symptoms that might be indicative of a cerebellar deficit Among these patients 35 were found to have such symptoms, 37 did not



Fig 2 Slightly enlarged sulci Primary fissure not over 4 mm in width



Fig 3 Cerebellum is small and the sulci measure over 4 mm in width

Results

The relationship found between the size of the cerebellar sulci and clinical findings referable to cerebellar disease is seen in Table 1

Normal cerebellar sulci A total of 33 patients were classified as having normal cerebellar sulci The average of the group was 40 5 years with a spread of the ages between 22 and 67 years Eight had symptoms referable to the cerebellum

Slight to moderate cerebellar cortical atrophy A total of 28 patients 42 5 years old on the average with an age spread from 31 to 63 years were classified as having a mild to moderate degree of cerebellar atrophy 17 of these patients had definite cerebellar symptoms and signs

Table 1

Relationship between size of cerebellar sulci and clinical findings in 72 cases

Cerebellar sulci	No of cases		Av age	No of patients with cerebellar symptom	
Normal	33		40 55	8 (24)	
Slight to moderately enlarged	28	39	42 5	17 (61)	69
Grossly enlarged	11		54 2	10 (91)	

Table 2

Relationship of the clinical symptoms with the size of the fourth ventricle cisterna magna and enlarged cerebellar sulci

	No of patients	No of patients with a large cisterna magna	No of patients with a large fourth ventricle	No of patients with large sulci
Cerebellar symptoms	35	9 (25 %)	4 (11 %)	27 (77 %)
No cerebellar symptoms	37	3 (9 %)	1	12 (33 %)

Marked cerebellar cortical atrophy Eleven patients were classified as having severe cerebellar atrophy The average age of the group was 54.2 years with a spread of ages from 41 to 71 years Of these cases, 10 showed moderate or severe symptoms indicative of cerebellar dysfunction

Large fourth ventricle and/or large cisterna magna The correlation between the clinical findings and the variations in size of the cerebellar sulci in patients with enlargement of the fourth ventricle or cisterna magna is evident from Table 2 Of the 35 patients with clinical suspicion of cerebellar dysfunction only 9 had enlargement of the cisterna magna Of the 37 patients without evidence of cerebellar dysfunction, 3 had enlargement of this structure Of 35 patients with symptoms of cerebellar disorder only 4 had an enlarged fourth ventricle according to the criterion of SUTTON (1950) Of these 4 patients, 3 also had large cisternae magnae The one patient with an enlarged fourth ventricle but without cerebellar dysfunction had a small cisterna magna

Discussion

The close correlation between the clinical and the direct radiologic findings in the group of patients with marked cerebellar atrophy shows the value of attempting to demonstrate the cerebellar sulci Only three of the patients with grossly enlarged sulci had indirect radiologic evidence suggesting a possible cerebellar defect, i e a large fourth ventricle and/or large cisterna magna If the sulci had not been demonstrated, therefore, a radiologic diagnosis of cerebellar atrophy could not have been made The one patient in this group without clinical evidence of a cerebellar deficit was a chronic alcoholic with mild dementia and clinical evidence of liver disease

Among the 72 cases studied, 39 had radiologic evidence of mild moderate or severe cerebellar atrophy and among these cases with abnormal cerebellar encephalographic findings, 27 (69 %) had clinical evidence of a cerebellar

Table 3

Clinical findings in eight patients with normal sulci and symptoms suggestive of a cerebellar deficit

Ag	Height of IV ventricle	Cisterna magna	Cerebellar findings	Clinical diagnosis
Ac 34	15 mm	small	Ataxic gait Head titubation	
Cr 49	10	small	Unable to tandem walk or stand on one foot Ataxia	Chronic alcoholism with several episodes of DTs
Do 67	21	large	Tremor Ataxia lower extremities	Ependymoma of L2 with block on myelogram Past history of cerebral hemorrhage requiring burr holes
Ed 33	16	large	Ataxic gait	Chronic alcoholism with cirrhosis Seizures Skull fracture one year ago
Lo 41	18	small	Unsteadiness of gait and posture	Epilepsy At least one episode of barbiturate intoxication
Re 42	16	small	Poor coordination and falling to either side Finger to nose and heel to knee tests — poor	Temporal lobe epilepsy with several episodes of dilantin toxication
Wa 57	16	small	Progressive gait difficulty	Generalized arteriosclerosis and secondary myelopathy
Wr 51	21	small	Nystagmus Mild ataxia	Chronic alcoholism Lennec's cirrhosis Autopsy — no gross cerebellar atrophy

deficit (Table 1) By contrast among the 33 patients with normal encephalograms only 24 % had signs of possible cerebellar dysfunction Among 37 patients without clinical evidence or suspicion of cerebellar disease, 12 had encephalographic abnormalities Of these, however 6 were severe alcoholics and may well have had occult cerebellar atrophy LICHTENSTEIN & LEVINSON (1946) have shown that gross cerebellar atrophy may be present in the absence of specific cerebellar clinical symptoms



Fig 4 From a patient with hereditary olivopontocerebellar degeneration The cerebellar sulci are slightly enlarged and the fourth ventricle and cisterna pontis are large

Of the 33 patients whose sulci appeared normal 8 had symptoms referable to the cerebellum Table 3 gives the clinical diagnosis in these patients, 6 *of them were patients with chronic alcoholism or were epileptics who had* received dilantin for many years One patient, a 67 year old man with hypertensive vascular disease, had a very large cisterna magna and a fourth ventricle measuring 21 mm in height, and it would seem probable that the patient had atrophy which was more marked in the hemispheres than along the midline structures where the sulci are outlined best

Two of the patients classified as having only slight cortical atrophy were patients with hereditary olivopontocerebellar degeneration The fourth ventricle was enlarged in both of these patients and the pontine cisterns were enlarged, measuring 12 mm in both Fig 4 shows the findings in one of these cases At necropsy these two patients had gross atrophy of the pons and some generalized cerebellar atrophy, but the atrophy was maximal in the hemispheres and the vermis was grossly only slightly abnormal Since it often is not possible to differentiate clinically between olivopontocerebellar and chronic cortical degeneration, encephalography may be determinative

The difference in the average ages of the group with normal cerebellar sulci, 40.5 years, and the group manifesting severe atrophy 51.5 years, is significant Only 3 of the 33 patients with normal sulci were over 60 years of age while 5 *of the 11 patients with marked cerebellar atrophy were over 60* years of age All but one of the patients with severe atrophy had enlargement of the lateral and third ventricles An increase in ventricular size commonly

occurs with aging but it seems unlikely that severe peripheral cortical atrophy can be explained by an age factor alone This concept is supported by the observation that in the patients with normal studies as opposed to those with slight moderate atrophy there was no significant age differential

The demonstration of the cerebellar sulci depends more on the position of the head during the introduction of the air at encephalography than on the amount of gas used UZMAN (1948) attempted total replacement of fluid in five patients with cerebellar symptoms and only in one of them was there adequate filling of the sulci to demonstrate the folia Recent superb studies by THIÉBAUT WACKENHEIM & VROUSOS (1959) have outlined the most reliable maneuvers to be followed for filling the sulci The same authors, as well as EPSTEIN & DAVIDOFF (1946) DICHIRO (1964) and BASSANI & AMICI (1960) have stressed the value of tomography during encephalography The cerebellar sulci demonstrated most readily at encephalography are those of the vermis, fortunately the majority of cases of cerebellar atrophy are represented by the nutritional alcoholic group and in these it is predominantly the cerebellar vermis which undergoes degeneration (VICTOR et coll 1959)

SUMMARY

The results indicate that encephalography has a definite value in disclosing and diagnosing the presence of cerebellar atrophy and is probably more useful than the indirect criteria based upon enlargement of the cisterna magna and/or fourth ventricle

ZUSAMMENFASSUNG

Die Ergebnisse weisen darauf hin dass der Encephalographie beim Nachweis und fur Diagnosestellung von cerebellarer Atrophie ein eindeutiger Wert zukommt Diese Untersuchung ist wahrscheinlich wichtiger als die indirekten Kriterien die bei Vergrosserung der Cisterna magna und/oder des vierten Ventrikles in Erscheinung treten

RÉSUMÉ

Les résultats des auteurs montrent que l encéphalographie a une grande valeur pour le diagnostic de l atrophie cérébelleuse et est probablement plus utile que les critères indirects basés sur l agrandissement de la grande citerne et/ou du quatrième ventricule

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FROM THE DEPARTMENTS OF RADIOLOGY AND NEUROSURGERY THE ROYAL INFIRMARY SHEFFIELD ENGLAND

THE CAROTID CISTERN A SOURCE OF DIAGNOSTIC DIFFICULTIES WITH SUPRASELLAR EXTENSIONS OF PITUITARY ADENOMATA

by

N A Lewtas and A A Jefferson

When studying patients with chromophobe pituitary adenomata we have frequently observed discrepancies between the dimensions of the suprasellar portion of the lesion as they appear at encephalography and as found at operation Air which projects over the suprasellar region in lateral films but which lies lateral to the midline is the source of this disparity We have come to realise that one of the most important regions in which this air collects is around the carotid artery Because this periarterial subarachnoid space is large we shall refer to it as the carotid cistern

It is the purpose of this communication to describe and to illustrate the radio graphic appearances of the carotid cistern and to describe the techniques available for overcoming the difficulties which its presence creates

One of the reasons why the precise suprasellar extent of a pituitary adenoma cannot easily be recognised is because its anterior wall is rarely seen In a consecutive series of 33 encephalographies for chromophobe pituitary adeno mata we have outlined the anterior border of the suprasellar portion of the tumour on only three occasions

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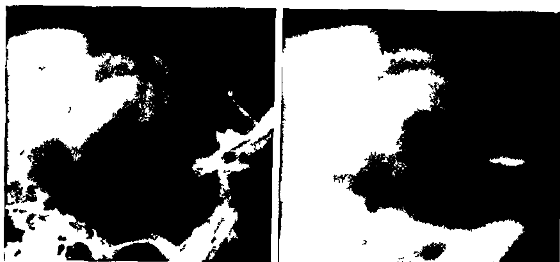
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N A LEWTAS and A A JEFFERSON

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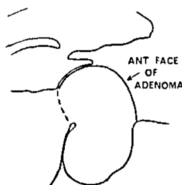


Fig 1 *Left* Lateral encephalogram A large suprasellar extension of a chromophobe adenoma deforms the front of the third ventricle Only the apex of the lesion is outlined Subarachnoid air overlies the suprasellar region *Right* A midline sagittal tomogram outlines the anterior border of the tumour Despite tomographic blurring parasellar subarachnoid air is still apparent

Results

An enlarged sella and also a clear indentation of the antero inferior aspect of the third ventricle are seen in Fig 1 Because the suprasellar region is obscured by irregular collections of air it would be hard to define the true outlines of the tumour The approximate position of the posterior wall of the adenoma may be derived from a line joining the posterior clinoid processes to the lowest part of the indentation in the third ventricle However, the anterior face of the lesion would be drawn in by guess work alone were it not for the information provided by the tomogram where the convex anterior face of the suprasellar portion of the adenoma is well seen

A similar appearance is shown in Fig 2 in which the anterior wall of a (partially calcified) adenoma was well outlined during routine encephalography *In our third case the findings were almost identical We feel it necessary* to stress this appearance because numerous authorities have given credence to

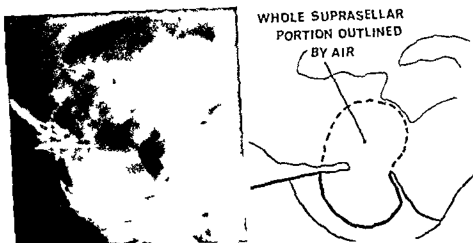


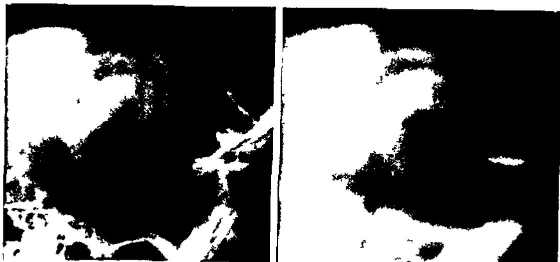
Fig 2 Later l encephalogram Fortuitous del neation of the whole suprasellar mass

the view that the suprasellar portion of the adenoma may consist only of a triangular portion involving the posterior part of the suprasellar region

An example of this artefact from our own series is illustrated in Fig 3 (*top*) A film obtained later in the examination showed the third ventricle to be indented by a tumour which was far larger than the triangular portion previously indicated We feel strongly that the interpretation suggested in the schematic diagram must always be incorrect for the surgical findings with such lesions are consistently those shown in Fig 4 where the lesion bulges forwards *between* the optic nerves and is contiguous with the tuberculum sellae

Sometimes the artefact present in the suprasellar region takes the form of an M (Fig 5) At other times and perhaps only in the atrophic brain there may be a large sheet of air which completely obscures the whole suprasellar region (Fig 6)

In order to understand the origin of these appearances one must consider the normal anatomy It has long been recognised that the carotid artery may be seen in the lateral projection during encephalography We suggest that the presence of air adjacent to the carotid artery helps to create the artefacts illustrated in Figs 3 and 5 The subarachnoid space which surrounds the carotid artery is in most anatomical descriptions (e g LILIEQUIST 1959) merely listed as part of the cisterna chiasmatis However when one explores the carotid artery surgically one invariably finds a capacious space around it We propose to refer to the large subarachnoid space which surrounds the



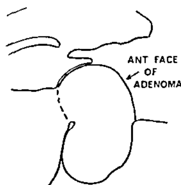


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Fig 4 Operation photograph Suprasellar mass bulges forwards medial to right optic nerve and contiguous with tuberculum sellae



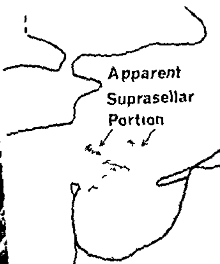


Fig 5 Lateral encephalogram Subarachnoid air gives false M shaped outline of adenoma True site of lesion shown by third ventricle

internal carotid artery as the carotid cistern The extent of the carotid cistern can be recognised on tomography and in some cuts the carotid artery may be seen within it In *Fig* 8 comparison between *the* straight film and a tomographic cut in the midline clearly discriminates between air lying in the

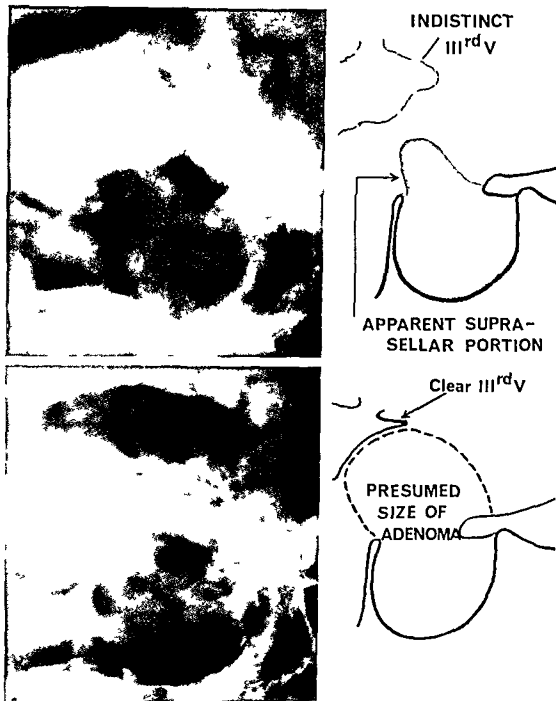


Fig 3 Lateral encephalograms *Top* Third ventricle indistinct Subarachnoid suprasellar air creates false outline of tumour *Bottom* Later film True size of tumour shown by indented third ventricle

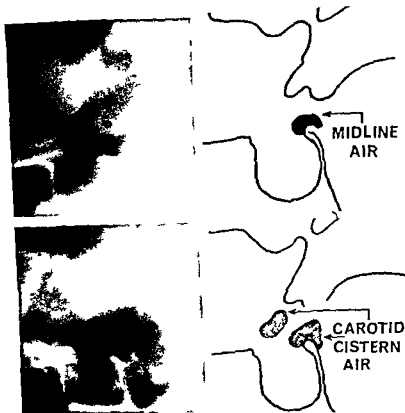


Fig 8 Intrasellar chromophobe adenoma *Top* Sagittal tomogram shows only a small amount of air in the midline *Bottom* Conventional film shows much larger quantity of air in carotid cistern

reproduces the films of a patient with a massive suprasellar tumour in whom the third ventricle was not clearly seen on any of the films There was no significant enlargement of the lateral ventricles and the fact that the foramen of Monro was almost occluded was not recognised In consequence of this error this patient underwent operation and died some 36 hours later This occurred 10 years ago and if we had then realised the true proportions of this lesion operation would have been strictly avoided

Because in our opinion it is vitally important clearly to see the antero inferior limits of the third ventricle we have considered how this may be achieved with certainty We have reviewed the encephalograms of a series of operable cases (i e those without massive suprasellar extensions) Among twenty nine patients the antero-inferior limits of the third ventricle were

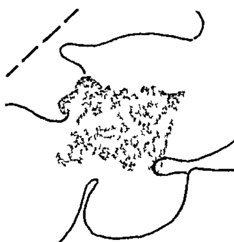



Fig 6 Lateral encephalogram in patient with relatively small suprasellar mass and cerebral atrophy Large sheet of air obscures suprasellar region

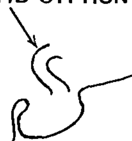



Fig 7 Normal lateral air encephalogram in which the internal carotid artery is clearly outlined by air

midline and air lying more laterally surrounding the carotid syphon It will be noted *that the air in the carotid cistern is by far the larger collection* In coronal tomograms the carotid cistern may also be demonstrated In Fig 9, there is relatively little air in the sylvian fissure, but if there is extensive cerebral atrophy a large amount of air may become trapped along its length (Fig 10) This air, when viewed in the lateral projection may densely obscure the suprasellar region (see Fig 6)

Clear demonstration of the third ventricle, or failure to identify it can literally make the difference between life and death For example Fig 11

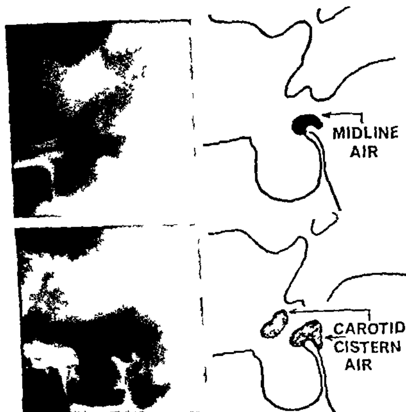


Fig 8 Intrasellar chromophobe adenoma *T p* S gittal tomogr m shows only a small amount of a r in the m dline *B tt m* Convent onal film shows much larger quant ty of a r in carot d cistern

reproduces the films of a patient with a massive suprasellar tumour in whom the third ventricle was not clearly seen on any of the films There was no significant enlargement of the lateral ventricles and the fact that the foramen of Monro was almost occluded was not recognised In consequence of this error this patient underwent operation and died some 36 hours later This occurred 10 years ago and if we had then realised the true proportions of this lesion operation would have been strictly avoided

Because in our opinion it is vitally important clearly to see the antero inferior limits of the third ventricle we have considered how this may be achieved with certainty We have reviewed the encephalograms of a series of operable cases (i e those without massive suprasellar extensions) Among twenty nine patients the antero inferior limits of the third ventricle were

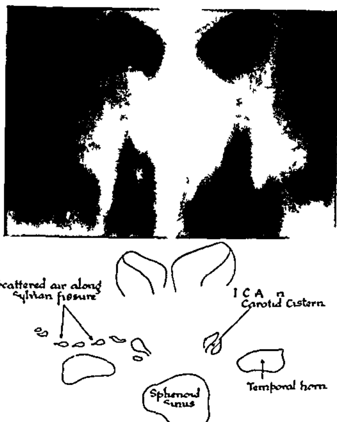


Fig 9 Pituitary adenoma (see also Figs 4 and 13) Coronal tomogram shows left internal carotid artery within the carotid cistern

not recognisable in eight, they were difficult to define in six, and were well seen in fifteen Thus, using old methods of encephalography we were failing precisely to outline the area critical to the investigation in half our patients Originally, this deficiency did not greatly trouble us, because our main aim during encephalography with these patients had been to certify the case as suitable for surgery by excluding the presence of a massive suprasellar lesion However, because there will always be a small proportion of patients in whom the clinical diagnosis is in doubt we feel that precision in the routine techniques is essential Tomography provides the chief means by which the antero inferior portion of the third ventricle may be clearly seen We have employed sagittal 'cuts' in the brow up position using a vertical arc of tube swing This invariably gives a clear outline of the anterior portion of the third ventricle, and eliminates to a considerable extent overlying subarachnoid air An example of this technique is shown in Fig 12 where the straight lateral projection shows only a small suprasellar mass whose size cannot be

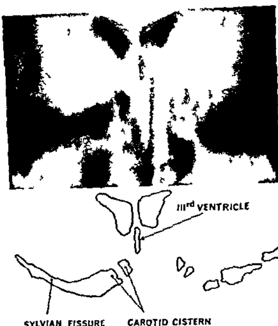


Fig 10 Same patient as in fig 6 Coronal tomogram shows large collection of air in sylvian fissure and carotid cistern

properly estimated because the third ventricle remains indistinct The tomogram shows the true size of the tumour

An additional virtue of tomography is that by revealing obliteration of the midline portion of the cisterna chiasmatis it will help to reveal the presence of relatively small adenomata which are large enough to compress the visual pathways but too small to distort the third ventricle to any great extent Fig 13 reproduces a film from a patient with suspicious visual changes and with an almost normal supraoptic recess However in this case the air which lay in the pontine cistern outlined the posterior face of the suprasellar mass In cases in which the suprasellar mass is relatively small and the third ventricle lies anatomically either high or posterior or both relative to the pituitary fossa midline sagittal tomography would obviously assist correct diagnosis

Because the necessary specialized apparatus for the brow up sagittal tomographic cuts may not always be available, we have also studied two alternative techniques The first and more elegant of these is to employ auto tomography With care one may achieve results which match those so beautifully illustrated by SCHECHTER & GUTIÉRREZ MAHONEY (1962) The second alternative makes

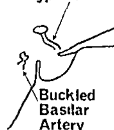
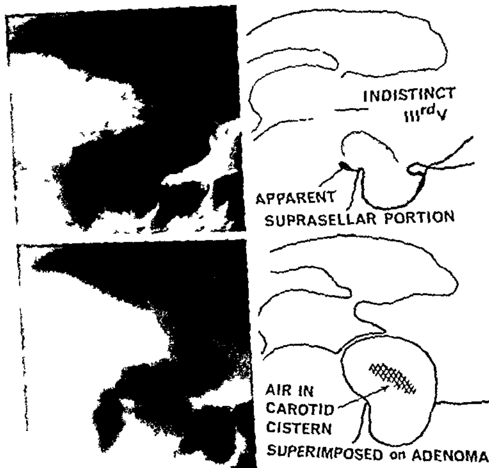



Fig. 11. Lateral encephalogram with massive suprasellar adenoma. (The third ventricle was not seen in any of the films.) Deformation of carotid and basilar arteries.

use of the old observation that, following encephalography, the subarachnoid air disappears before the intraventricular air. Fig. 14 illustrates a patient in whom, on the initial roentgenograms, the third ventricle was not clearly defined, and the air in the basal cisterns thoroughly obscured the suprasellar region. Twelve hours later the subarachnoid air had almost all been absorbed and a lateral film, taken with the head over extended, allowed a considerable indentation in the front wall of the third ventricle to be clearly recognised. It should be noted that the small collection of apparently suprasellar air in Fig. 14 (top sketch) must actually lie laterally in the carotid cistern. It is possible to make this statement categorically for these films relate to the same patient whose operation findings have been illustrated in Fig. 4.

Discussion

Every surgeon who operates in the postero medial subfrontal region will be familiar with the amount of cerebrospinal fluid which escapes from around the internal carotid artery whenever the cistern which contains it is first opened. It was when we realised the capaciousness of this subarachnoid space that we sought to discover whether air contained within it could obscure the suprasellar region when viewed in the lateral projection. It is the size of this subarachnoid



F g 17 *Top* Lateral nc phalogram *stra ght la eral* p ojection S nall sup asellar mass third ventr cle and st ct *B tt m* Sagittal tomogram Delo n ed third ventricle shows true si e of tumour p sell r a s till is ble in midl ne cut

space as seen at operation and as *demonstrated* by tomography (see Figs 8, 9 and 10) that has made us wish to *identify it* as the carotid cistern Since the capacity of the carotid cistern is far larger than the central portion of the cisterna chiasmatis it seems logical to differentiate between them We feel that there is every reason to *suppose that* confusing artefacts of the types displayed in Figs 3 and 5 are caused by air *which* is pooled in the carotid cisterns

Haas in 1925 made the suggestion that encephalography would allow one to define the upper border of the pituitary gland However it was Heidrich (1928 and 1929) who first *reported using* encephalography in an attempt to



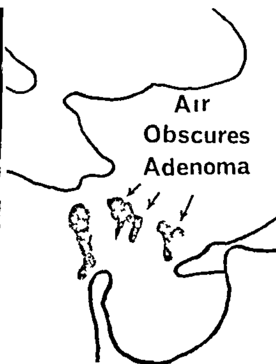


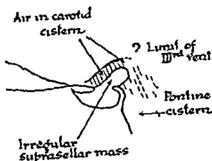
Fig 13 Lateral encephalogram Third ventricle lies high and posterior to tumour and is little deformed Only posterior face of tumour is outlined

determine the suprasellar extent of pituitary adenomata He studied the changes in the basal cisterns and was anxious to avoid intracranial operations with massive lesions HEIDRICH was also concerned to distinguish between tumours which were mainly suprasellar and those which were mainly intrasellar He wished to use this information to decide whether operation should be undertaken via the nasopharynx or intracranially

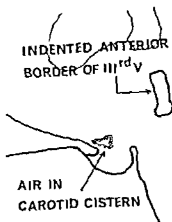
The next serious attempt to add precision to encephalography was that of DYKE & DAVIDOFF (1934) who studied particularly the changes in the basal cisterns in a wide range of pathological lesions With pituitary adenomata, they reported changes similar to those described by HEIDRICH, but like him they did not refer specifically to the diagnostic deformities of the third ventricle

In 1940 BALADO & ORIBE described a technique in which they used encephalography associated with stereoscopic radiography in the extended head position They described a series of four cases investigated by this means and claimed that it gave great diagnostic precision They found that the increased *information* provided by stereoscopy helped them to recognise obliteration of the chiasmatic cistern by a suprasellar mass, together with elevation of the adjacent portion of the third ventricle They observed that, without stereoscopy these features were often obscured by superimposed air In the years that









g 14 Lateral ncephalograms (see also figs 4 and 8) *Top* Large amount of subarachnoid para llar a r obs u es all relevant deta l third vent icle not clearly seen *B ttom* Twel e hours later lost of sub rachnoid ai now absorbed and deformity of third ventricle s pla nly seen

ollowed this contribution encephalography came to be more and more ac epted as a routine measure in the investigation of pituitary tumours The vritings of BAKAY & WHITE (1953) and of DAVIDOFF & EPSTEIN (1955) bear witness to this process However in our hands at least until the last few years we tended when performing encephalography to be more interested in detecting the presence of tumours too large for surgery among a series of patients in whom on other grounds we had no reasonable doubt concerning the pathology Apart from the dangers inherent in inexact radiography we have for the past four years recognised the need for the greatest precision fol lowing an experience in which one of us (A J) was led to operate unneces sarily The patient had optic atrophy a clear bitemporal hemianopia an

enlarged pituitary fossa and a very short history. At operation, it was found that the adenoma had spontaneously infarcted and was confined within the pituitary fossa. In retrospect, the short history related to recent suprarenal insufficiency and the patient had ignored (preceding) bi-temporal hemianopia until hospital investigations made her aware of it. This error arose from failure clearly to demonstrate the antero-inferior portion of the third ventricle.

For many years it has been recognised that during encephalography overlying collections of air obscure the suprasellar region. TWINING in 1937 predicted that tomography would play an important part in resolving this kind of difficulty. He felt that it would "come more and more into routine use" and added that "if we ask it (tomography) the right questions, we shall get the right answers." TWINING's forecast was confirmed by the appearance of studies such as those of EPSTEIN & DAVIDOFF (1946) which was concerned with midline tumours, and of LOMBARDI (1949) which so beautifully illustrated the normal basal cisterns.

Tomography provides an invaluable means of displaying the *midline portion of the cisterna chiasmatis*, of occasionally showing the anterior border of the lesion, and it is a method which should invariably be employed when there is real diagnostic difficulty. We cannot emphasise too strongly that, in the presence of suprasellar masses, most of the air which appears suprasellar in position (in the lateral film) is in reality lateral to the midline. The importance of identifying the plane in which this air is lying has been recognised by others. BONNANT (1953) who had failed to solve the problem by tomography, attempted to do so with stereoscopic radiographs. Stereoscopic techniques were also used, as mentioned above, by BALADO & ORIBE (1940) and by DAVIDOFF & EPSTEIN (1955) for the study of the basal cisterns. These last workers had previously been successful in displaying clearly the third ventricle by means of tomography (EPSTEIN & DAVIDOFF 1946).

PALEIRAC, LABAUGE & BASSEDE (1953) described the use of tomography with the head over-extended to show the dispersal of air in the basal cisterns. They obtained "cuts" in the midline and 1 cm to each side of it, and remarked that this technique eliminated vascular structures which were superimposed on pathologic processes. (No further details on this point were given, however.)

Although autotomography with encephalography was originally described in 1950 by ZIEDSES DES PLANTES, for some curious reason its merits were generally ignored for many years. Its value was however recognized by SCHVARCZ (1959), who also modified the technique. SCHECHTER & GUTIÉRRIEZ-MAHONEY in 1962 published a comprehensive report brilliantly displaying the possibilities of the method. Certainly autotomography when

carefully performed brow up with the neck fully extended will provide excellent detail of the front of the third ventricle (cf SCHWARCZ 1959) The less satisfactory technique of repeating the lateral views after the overlying subarachnoid air has been largely absorbed has very real limitations for one is automatically bound to remain ignorant of the contours in the space above the sella and below the brain In this we agree with SCHWARCZ

Only by a full understanding both of the ways in which difficulties of interpretation arise and of the means by which such difficulties may be surmounted can we hope to arrive at consistently correct diagnosis and thus to offer appropriate treatment to our patients

Acknowledgements

Figures 1 8 9 10 and 12 are a tribute to the skill of Mr A Robson F S R and we are grateful to him for his help The remaining figures have been obtained by Miss J M Osborne and her staff at the Royal Infirmary to all of whom we continue to be greatly indebted It is a pleasure to record our thanks to Mr G Swann of the Photographic Department for his careful work in preparing the illustrations and to Miss A Mason whose typing never needs correction

SUMMARY

Because the third ventricle may not be completely outlined by conventional techniques during air encephalography it is often difficult to define the precise suprasellar extent of chromophobe adenomata The commonest cause is air surrounding the carotid artery and obscuring the suprasellar region in the lateral projection The difficulties may be circumvented by employing tomography

ZUSAMMENFASSUNG

Da bei konventionell r Luftencephalographie der dritte Ventrikel unvollstandig gefullt sein kann ist es oft schwierig die suprasellare Ausbreitung von chromophoben Adenomen zu bestimmen Die haufigste Ursache hi rfur ist dass die Luft die Art carotis umgibt und in der Seitenprojektion die suprasellare Region uberlagert Diese Schwierigkeiten konnen mittels Tomographie vermi den werden

RÉSUMÉ

Il arri e qu il ne soit pas possible d étudier completement le troisieme ventricule par les techniqu s clas iques d encéphalographie gazeuse ce qui rend souvent diff cile la délimitation preci e de l extension suprasellaire des adénomes chromophobes La cause la plus commune est l air qui entoure l artère carotide t se superpose à la région suprasellaire sur la radiograph de prof l Ces diff cultés peuvent être évitées par l emploi de la tomographie

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UNIVERSITY OF WASHINGTON SCHOOL OF MEDICINE SEATTLE WASHINGTON, U S A

A DEVICE FOR ENCEPHALOGRAPHY IN INFANTS

by

JOHN W LOOP

Encephalography in infants and small children presents a variety of technical problems Moving the very young into proper position for exposing the films may be rather difficult because of the relatively large and heavy head compared to the tiny trunk Apparatuses which are scaled to adult dimensions are often not easily adaptable to children Normally the smooth routine is frequently disrupted because the examiner needs to improvise These problems are to some extent aggravated by the predictable non cooperation of wakeful infants and the encumbrances of those who have been anesthetized For these reasons it was thought useful to develop a special device for handling infants during encephalography

The figure shows a free standing metal frame with closed transparent upper sections and adjustable shoulder and hip yokes and foot plate The patient is enclosed within this frame and strapped to the shoulder and foot sections These with the *hip section* can be raised until the head is inside the closed upper part Here it is centered and fixed by inflating a pair of transparent bag Head tilting and rotation are thus eliminated and the head and trunk thereafter move together a a unit The unit can be quickly moved from position to position and either forward or backward somersaults (controlled encephalography) can be accomplished with ease The design permits exposing of films in inverted positions and allows identical frontal projections in right and left lateral recumbency, as well as standard encephalographic views

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Figure Device for holding infants for encephalography The two inflatable plastic bags used to center and secure the patient's head may be removed

Fluoroscopic and cinematographic examination is also convenienced by this system of immobilization

SUMMARY

A device for positioning infants and small children for encephalography is described

ZUSAMMENFASSUNG

Eine Vorrichtung zur Lagerung und Fixierung fur die Encephalographie bei Sauglingen und Kleinkindern wird angegeben

RÉSUMÉ

Description d'un dispositif pour maintenir les nourrissons et les petits enfants pendant l'encéphalographie

FROM THE DIVISION OF NEUROLOGY, DEPARTMENT OF MEDICINE UNIVERSITY OF MADRID MADRID SPAIN

PAN VENTRICULOGRAPHY

A new technique utilizing emulsified Pantopaque

by

ALBERTO PORTERA

LUCKETT (1913) accidentally discovered air outlining the ventricular system in a routine roentgenogram of the skull in a man with a skull fracture Since then much effort has been directed towards finding an ideal contrast medium for delineation of the ventricular system and subarachnoid space Since the development of air ventriculography and encephalography by DANDY (1918—1919) air has been used as an excellent contrast medium despite the frequently disagreeable side effects Through wide use this technique has been perfected to such a degree that it is now possible to outline practically all of the cerebrospinal fluid containing cavities and hence to assess abnormalities within them However these techniques in general commonly require the use of such special equipment as tilting chairs and tomographs as well as multiple injections of air with numerous roentgen exposures and consequent discomfort to the patient

In addition to interpret this series of positional films correctly a high degree of skill and experience is needed and the proper use of air as a contrast medium has therefore become limited to well trained neuro radiologists and those departments where the above mentioned special equipment is available

These considerations have led to further studies to find other contrast media and more simplified techniques.

BALADO (1928) introduced Lipiodol into the ventricular system through a burr hole, and by using multiple exposures of the head in various positions he was able to obtain a complete survey of the ventricular system. Since then, this method has been in wide use but Pantopaque has replaced Lipiodol because of its less irritating qualities. MATSUBARA (1960) used isobaric Lipiodol emulsified with a neutral isotonic solution prepared with sodium lauryl sulphate. He was able to obtain complete demonstration of the ventricular system without apparent complication. The use of these oily contrast media has some advantage over air since they are painless and the patient's only discomfort is the troublesome head positions. However, their non-absorbability is a disadvantage because frequently, several ml must be injected in order to obtain complete demonstration of the ventricular system. This particular disadvantage has led to the use of the presently available absorbable contrast media for injection into the ventricles. Unfortunately, recent communications (CAMPBELL 1964) have indicated that frequent and severe complications limit their utilisation in man. More recently DI CHIRO (1964) has introduced RISA into the ventricular system to supplement information found by examinations using air as the contrast medium. His paper cites some of the disadvantages of air. He found RISA ventriculography especially useful for detecting intraventricular tumors and internal hydrocephalus, and concluded that RISA ventriculography has a definite place among neuroradiologic diagnostic methods.

The work of BLEASEL (1961) using emulsified Pantopaque for lumbar myelography prompted us to use this technique for our own myelographies. As the complications were no greater than with ordinary Pantopaque and as emulsified Pantopaque is less dense, we introduced the use of this emulsion in those cases in which ventriculography was indicated.

Method

The surgical technique is the same as in classical ventriculography with air but only one burr hole is needed. Only local anesthesia is required. A right frontal burr hole is made and the patient is placed on the radiographic couch in the supine position with the head flexed by using a radio transparent prop. The roentgen tube is positioned to take a lateral roentgenogram with the usual settings for a standard skull film, with an exposure time of less than half a second, if possible.

A ventricular cannula is introduced through the burr hole (or through the fontanel in the case of an infant) into the frontal horn of the right lateral



a b

Fig 1 Case 1 a) Film taken about 2 sec after injection of the emulsion (2 ml Pantopaque and 6 ml cerebrospinal fluid) The ventricular system is outlined in detail Abnormal angulation in upper part of aqueduct b) Anteroposterior projection obtained without moving the patient Asymmetry of 4th ventricle with flattening of right lateral recess

ventricle An amount of 8 to 15 ml of ventricular fluid is collected in a sterile 20 ml syringe depending on the expected size of the ventricle Pantopaque in an amount approximately one fourth of the volume of the spinal fluid collected is introduced into the syringe In addition 5 ml of air is also introduced into the same syringe to facilitate emulsification A sterile cap is applied to the syringe and it is then shaken vigorously for 20 seconds The exact proportion of Pantopaque to ventricular fluid is not critical for we have used a range of ratios from 1/6th to 1/3rd of the spinal fluid with equally satisfactory results Higher concentrations are recommended in children with obstructive hydrocephalus with extremely large ventricles

The air in the syringe is then ejected and the milky emulsion is injected into the ventricle through the cannula The injection must be done rapidly and smoothly at the rate of an ordinary intramuscular injection

The intraventricular cannula should be left in place for 24 hours in cases in which a complete block is found This will allow removal of excessive ventricular fluid should it accumulate prior to a definitive surgical procedure

A lateral film is taken one second after the end of the injection Without moving the patient the position of the tube is changed and an a p film is taken (Fig 1 a and b) We have studied a series of lateral views taken with a film changer at half-second intervals starting at the beginning of the injection The Pantopaque in fine emulsified droplets enters the

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Figs 4—6 (cf figs 2—3) At the 3rd sec (upper left) the whole ventricular system is filled with contrast material At the end of the 4th sec (upper right) some contrast can be seen in the upper cervical subarachnoid space 5 min later (lower left) the emulsion has broken down and the Pantopaque has pooled in dependent areas including the cisterna magna

present Ventriculography Dilatation of the aqueduct and a block at the level of the fourth ventricle with marked displacement of the aqueduct and the fourth ventricle to the left demonstrated (Fig 7 a) At operation a large right sided acoustic neurinoma was found

Case 3 This 7 year-old child had a history of intermittent headache and difficulty with gait of five months duration Diplopia developed two months and nausea and vomiting two weeks prior to admission Examination revealed bilateral pyramidal tract disease and a bilateral internuclear ophthalmoplegia Fig 8 shows upward and backward displacement of the aqueduct Surgical exploration revealed a pontine tumor

Case 4 An 11 year-old boy with a six month history of constant diplopia and with difficulty in moving his left eye outward Intermittent headache and vomiting appeared one month



Figs 2—3 Films obtained with a rapid film changer At the end of the 1st second (left) the emulsion *has partially filled the lateral and 3rd ventricles* and in the second film (right) at the end of 2 sec the emulsion has filled the occipital horns of the lateral ventricles and entered the 4th ventricle

ventricle with a turbulence which results in extremely rapid and complete dispersal throughout the entire ventricular system Fig 2 shows the state of turbulence at the end of the first second and Figs 3 to 6 the distribution and rapid dispersal of the contrast medium during the first five minutes

In general, we have chosen the lateral position for the first film as it gives the most information for a survey of the entire ventricular system This is followed by obtaining an a p view without moving the patient, thus allowing a clear view of displacement of the midline portions of the ventricular system This sequence could be reversed in a particular case, or biplane serial films obtained if the equipment is available

To illustrate clinical examples where the value of this technique is evident, five cases will be briefly presented

Case reports

Case 1 A 23 year old girl with a history of severe headaches of six months duration and progressive loss of vision for one month On examination she showed marked bilateral papille dema and slight incoordination of the right hand In Fig 1 a and b slight dislocation of the upper third of the aqueduct and a flattening of the lateral recess of the fourth ventricle are clearly demonstrated At operation a tuberculoma of the right inferior pole of the cere bellum was found

Case 2 A 32 year old man presented with typical symptoms of a right acoustic neurinoma *of three years* duration On examination right sided deafness right facial hypalgesia and a mild right facial palsy of peripheral type were noted Bilateral severe papilledema was also



Fig 8 Case 3 Pontine tumor in a child Film taken a few seconds after the turbulence ceased Elevation and posterior displacement of the aqueduct

and 19 males The same indications for air ventriculography or ordinary Pantopaque ventriculography were used in the selection of cases that is the presence of clinical evidence of increased intracranial pressure In these cases the performance of encephalography is usually considered dangerous This method was also used in 3 patients for localization of landmarks prior to stereotactic thalamotomy for Parkinson s syndrome (Fig 10) During stereotactic surgery the commissures can be seen throughout the operation This method has proved very valuable for this type of operation where critical and permanent landmarks are indispensable

We have found this method specially useful in detecting displacements distortions or blocks of the midline portions of the ventricular system It is also valuable in outlining both temporal and occipital horns simultaneously In most cases the frontal horns and bodies of the ventricles can be seen if the film is taken during the state of turbulence immediately following the injection The use of a rapid film changer facilitates critical timing We have also found that the small amount of air which forms part of the emulsion is helpful in outlining the frontal horns of the injected side This air is liberated during the first minutes following injection as the emulsion breaks down

Diagnostically the technique has proved to be accurate and reliable In the 27 cases of suspected brain tumors studied 18 showed abnormalities of

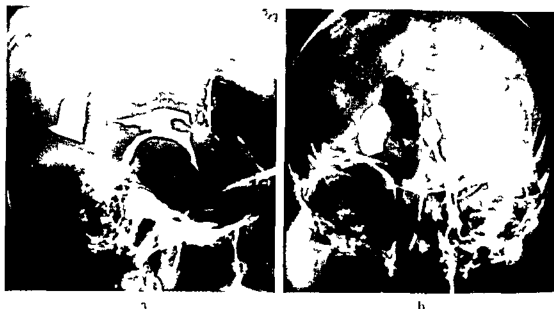


Fig. 7. Case 2. a) Lateral film in acoustic neurinoma. Elevation and dilatation of the aqueduct together with distortion of the 4th ventricle. Film taken more than four sec. after injection. Turbulence is no longer present. b) A.p. view. Displacement of 3rd ventricle and aqueduct and narrowing of 4th ventricle.

prior to admission. He also complained of paresthesias and pain in the left periorbital region. Examination revealed bilateral papilledema and a complete left sixth nerve palsy. He also had a diminished left corneal reflex and hypalgesia in the area of distribution of the first and second divisions of the left trigeminal nerve. Ventriculography: Hydrocephalus due to a block at the rostral end of the aqueduct was found as well as displacement of the floor and the posterior part of the third ventricle upward and laterally (Fig. 9 a and b). To obtain good contrast filling of the temporal horns, the head of the patient was brought from the brow up position to the brow down position. In Fig. 9 c a p.a. film shows marked elevation of the left *temporal horn, which appears collapsed. The space occupying lesion has also displaced the* anterior part of the third ventricle to the right. At operation a large tumor was found occupying a great part of the left middle fossa and displacing the temoral lobe upward. The tumor was found to extend, in dumb bell fashion, below the tentorium into the anterior portion of the left cerebello pontine angle cistern. Microscopic studies of the tumor revealed it to be a neurinoma which presumably originated in the left 6th nerve.

Case 5. A 45 year old patient with a five year history of rightsided parkinsonism was selected for stereotactic thalamotomy. Fig. 10 shows a lateral film taken while the patient was on the operating table with the craniostat in place. The emulsion clearly outlines the commissures of the third ventricle, which are the most commonly used landmarks for this type of surgery.

Discussion

We have now used this method in 38 patients, 13 children from 6 months to 13 years of age and 25 adults from 20 to 70 years of age. There were 19 females

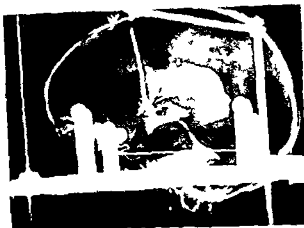


Fig 10 Case 5 Emulsified Pantopaque was used for delineation of the commissures of the 3rd ventricle in stereotactic surgery

than 24 hours Occasionally mild headaches were reported 4 to 8 hours after the procedure but these responded promptly to analgesics Two 13 year old children manifested a more severe febrile reaction accompanied by an aseptic meningitis syndrome Temperatures ranged to over 39 C but symptomatic treatment resulted in remission of symptoms and complete recovery in 48 hours Three infants under one year of age who had been subjected to the procedure by needle puncture of the anterior fontanel developed the mild febrile reaction seen in the adults We have now followed our patients for periods up to 18 months No symptoms attributable to Pantopaque have been found In some patients we were able to obtain roentgen films of the skull and lumbosacral region at random intervals of approximately 3 and 6 months They showed that most of the Pantopaque injected in the ventricles dispersed throughout the sacral roots much in the same manner as found after lumbar myelography A negligible amount of Pantopaque remained inside the ventricles

The mild toxic reactions seen in our groups of cases are in sharp contrast to the experience of JAEGER (1950) in his work with dogs He prepared Pantopaque in a colloid mill emulsifying it with artificial dispersing agents such as acacia The particle size achieved in the mill was in the order of 10 microns The emulsion was very stable and persisted through autoclave sterilization Following the injection of this emulsion into the ventricles of five dogs death occurred within the first 10 minutes in all animals He assumes in his paper that the tiny dispersed particles of the Pantopaque were responsible for the ill effects found in his dogs

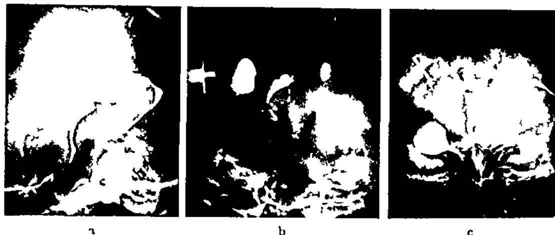


Fig 9 Case 4 a) Lateral film Complete block at origin of aqueduct The turbulence has disappeared Elevation of posterior part of floor of 3rd ventricle and dilatation of the ventricles b) A p view Film taken five minutes after the injection without moving the head The floor of the 3rd ventricle appears amputated and displaced upwards and to the right c) P a view By tilting the head forward both temporal horns and anterior part of 3rd ventricle are demonstrated The Pantopaque occupies the lowest portions of the ventricular system The neoplasm has elevated and collapsed the left temporal horn and displaced the anterior part of the 3rd ventricle to the right

the ventricular system suggesting the presence of a space occupying lesion In all abnormal cases a brain tumor was confirmed at surgery There have been no false positive studies This high degree of reliability is probably a result of the excellent detail with which the midline portions of the ventricular system are demonstrated In most cases two single films, a lateral and an a p projection, are necessary for correct localization of the lesion, in rare instances a third or fourth film may be required This may be obtained after making simple maneuvers of the head of the patient

This method can only be used for study of the ventricular system and through a burr hole Where demonstration of the cisterns is desired encephalography can be performed during the same diagnostic session The injection of air can be safely done via a lumbar tap because the danger of brain stem herniation is minimized following ventricular tap

It should be emphasized that this procedure is done under local anesthesia and is painless Thus, the patient may cooperate and this further simplifies the examination Since most of the information is obtained with two films, the need for multiple positional changes of the patient is eliminated Obviously the large number of films necessary with air or standard Pantopaque techniques are greatly reduced

Mild complications have been encountered In 28 cases low grade febrile reactions occurred, the temperatures were less than 39 C and persisted less

patient The anatomical detail achieved is impressive Because of the demonstration of the entire ventricular system in one film the interpretation is greatly simplified as compared to the complexity of analysing multiple films such as are required in air studies The technique does not limit the possibility of examining the subarachnoid cisterns with air at the same session

Only transitory side effects have been encountered and these have been generally less severe than those common to air ventriculography A specialized application of this method is the accurate localization of landmarks for stereotactic surgery We consider this method of special value in the study of posterior fossa or midline middle fossa lesions Also blocks of the cerebrospinal fluid pathways are readily demonstrated

In our experience to date, emulsified Pantopaque ventriculography has been the method of choice for studying the midline portions of the ventricular system in patients with increased intracranial pressure

SUMMARY

Pantopaque emulsified with cerebrospinal fluid from the patient under study has been used in cerebral ventriculography in 38 patients The entire ventricular system can be demonstrated in two films in the a p and lateral projections Side effects have been minimal and of short duration The examination is performed under local anesthesia and causes little or no discomfort Only 2 ml or less of Pantopaque are used for the emulsion

ZUSAMMENFASSUNG

Pantopaque emulgiert im Liquor des jeweiligen Patienten wurde bei 38 Patienten zur cerebralen Ventrikulographie verwendet Das gesamte Ventrikelsystem kann auf zwei Filmen in bzw a p und laterale Projektionen dargestellt werden Nebenwirkungen waren minimal und nur von kurzer Dauer Die Untersuchung wird unter Lokalanasthesie ausgefuhrt und ist mit wenig oder gar keinem Unbehagen verbunden Die Menge Pantopaque die fur die Emulsion benotigt wird betragt nur 2 ml oder weniger

RÉSUMÉ

L auteur a utilisé dans 38 cas en ventriculographie cérébrale une émulsion de Pantopaque dans le liquide céphalorachidien du malade On peut mettre en évidence la totalité du système ventriculaire sur deux films en incidence de face et de profil Les effets secondaires ont été minimes et de courte durée L examen est fait sous anesthésie locale et n est que peu ou pas pénible Il ne faut que 2 ml ou moins de Pantopaque pour l émulsion

With our technique the emulsification is achieved by manually shaking Pantopaque with the cerebrospinal fluid of the patient No artificial dispersing agents are used The size of the droplets is extremely variable and has been measured as being from 20 to 400 microns The resulting emulsion is very unstable In Fig 6 the film was taken 5 minutes after the injection of the emulsion It is readily seen that it has broken down and that the Pantopaque has pooled in the dependent portions of the ventricular system

In view of the differences between our study and JAEGER s work with dogs, it is possible to speculate that the size of the droplets or the nature of the dispersing agent may be responsible for the production of complications Perhaps the small size of the particles increases ependymal and arachnoid irritation because of longer lasting contact with the membrane surfaces

We have recently obtained findings from a postmortem examination of a child who was subjected to our method of ventriculography about one year ago At that time the diagnosis of obstructive hydrocephalus was made and was subsequently surgically alleviated by a shunt procedure The patient did well for more than a year but died of injuries sustained in an automobile accident Careful microscopic study of the ventricular ependyma and the arachnoid membranes of the posterior fossa revealed no abnormalities Roentgen examination of the removed brain failed to show any Pantopaque within the ventricles or in the subarachnoid space

Our experience with this type of emulsification of Pantopaque has been without severe complications Because of the short duration of the emulsion due to large particle size this procedure is tolerated in the same manner as standard Pantopaque ventriculography This contrast medium has been widely used for over 20 years as the best available compound for myelography There have been occasional clinical reports of unfavorable reactions of the use of Pantopaque but repeated experiments with laboratory animals have failed to demonstrate anything but minimal transitory reactions when injected in the subarachnoid space (MEACHAM 1963) *Another factor which should* contribute to minimizing the possible toxic effects of Pantopaque with our method is the small volume used Normally this is less than 2 ml in contrast to the 6 to 9 ml generally used in myelography

Conclusions

A simple technique utilizing emulsified Pantopaque for study of the ventricular system is offered No special neuroradiographic equipment is required The time needed to perform the examination is much less than with air or Pantopaque ventriculography Little or no discomfort is experienced by the

patient The anatomical detail achieved is impressive Because of the demonstration of the entire ventricular system in one film the interpretation is greatly simplified as compared to the complexity of analysing multiple films such as are required in air studies The technique does not limit the possibility of examining the subarachnoid cisterns with air at the same session

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Our experience with this type of emulsification of Pantopaque has been without severe complications. Because of the short duration of the emulsion due to large particle size this procedure is tolerated in the same manner as standard Pantopaque ventriculography. This contrast medium has been widely used for over 20 years as the best available compound for myelography. There have been occasional clinical reports of unfavorable reactions of the use of Pantopaque but repeated experiments with laboratory animals have failed to demonstrate anything but minimal transitory reactions when injected in the subarachnoid space (MEACHAM 1963). Another factor which should contribute to minimizing the possible toxic effects of Pantopaque with our method is the small volume used. Normally this is less than 2 ml in contrast to the 6 to 9 ml generally used in myelography.

Conclusions

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FROM THE NEURORADIOLOGIC DEPARTMENT (DIRECTOR PROF GIOVANNI RUGGIERO) OF THE OSPEDALE MAGGIORE BOLOGNA BOLOGNA ITALY

ENCEPHALOGRAPHY TODAY

Refinements in technique and progress in diagnosis

by

GIOVANNI RUGGIERO

The present paper received the privilege of opening the scientific session of the VII Symposium Neuroradiologicum I take this as a sign that its subject is still of great interest to neuroradiologists Neuroradiologic techniques have recently become quite popular and consequently there is at present a certain tendency to make use of examinations which are technically relatively easier than encephalography which is a complicated procedure requiring skill in performance After fifteen years of experience I am however more convinced than ever that encephalography is still and by far the most accurate means of investigation for a proper radiologic diagnosis of cerebral lesions This is emphasized by Fig 1 which shows the incidence of encephalography in our department where it is the second most frequent examination after carotid angiography

In 1957 I published a monograph (7) summarizing our past experiences with encephalography The main purpose of the present paper is to point out the progress that has been achieved since then This progress has been twofold better technique and more accurate diagnosis These two factors are interdependent and cannot be discussed separately

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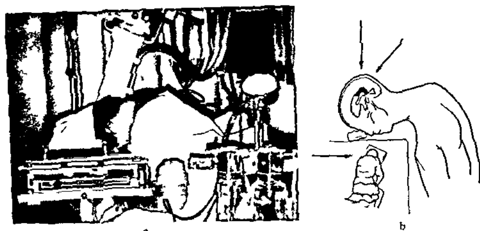


Fig 2 Examination of occipital horns in sitting position a) Position of patient The manometer for measuring the arterial pressure is incorporated in the set up for the general anesthesia and remains attached to the patient arm during the entire examination b) Centering for lateral postero anterior and half axial postero anterior projections The head is slightly extended but this does not influence the quality of the roentgenograms only the fluid level appears slightly oblique

amplifier television system with those obtained from the use of the Mimer With the present system it is however difficult to use the image intensifier in the frontal projection in the sitting position and impossible when the patient is lying down (We have not had an opportunity to use Mimer II which is especially constructed for encephalographic examinations using image amplifier TV and was presented at the XI International Congress of Radiology in Rome 1966

Examination of occipital horns in sitting position This is carried out shortly after investigating the posterior fossa structures and before examining the frontal horns (9) With our present technique (Fig 2) the temporal horns can be rapidly investigated by performing a simple manoeuver which does not necessitate the patient being previously in the prone position during the examination it is surprising how greatly this simplifies the whole technique especially when dealing with fat or deformed subjects for whom the centering can be difficult also in the prone position In the sitting position the fluid level in the ventricular carrefour or the posterior portion of the temporal horn may appear oblique in patients in whom it is not possible to obtain a complete flexion of the neck but this does not interfere with the diagnostic value of the radiographic images

A simpler manoeuver for filling the temporal horn LINDGREN (4) has demonstrated the necessity of studying the temporal horn in the supine position taking

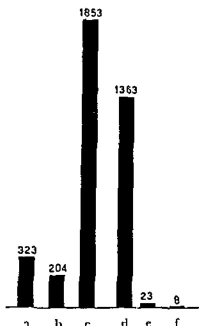


Fig 1 Cerebral contrast examinations at the Neuroradiologic Department of Ospedale Maggiore between November 1st 1961 and June 7th 1964 a — Percutaneous vertebral angiography b — Percutaneous external carotid angiography c — Percutaneous common and internal carotid angiography d — Fractional encephalography e — Gas ventriculography f — Positive contrast ventriculography

Our radiographic technique

At the symposium, a movie showing the present technique in detail was presented

Utilisation of an image intensifier under television control An image intensifier is now used routinely in our department This allows a shorter examination time than earlier, especially that part which is carried out with the patient in the sitting position, and makes the examination much better tolerated

Using the image amplifier, it is possible to check quickly whether the contrast medium has passed into the desired portion of the ventricular system or subarachnoid space whether it is equally distributed within the two lateral ventricles, and whether the amount of air injected is sufficient It is also possible to evaluate rapidly the success of some special manoeuvers as for instance, those for filling the temporal horn or the antero inferior portion of the third ventricle One important point needs to be emphasized however the images observed on the television screen can never be regarded as a substitute for the films, and have no diagnostic value unless they are recorded radiocinematographically It is also essential that the intensifier TV unit be fixed in such a way that none of the basic principles of the encephalographic technique as first established by LINDGREN (5) have to be set aside We use a set up designed for our department with the aim of combining the advantages of the image

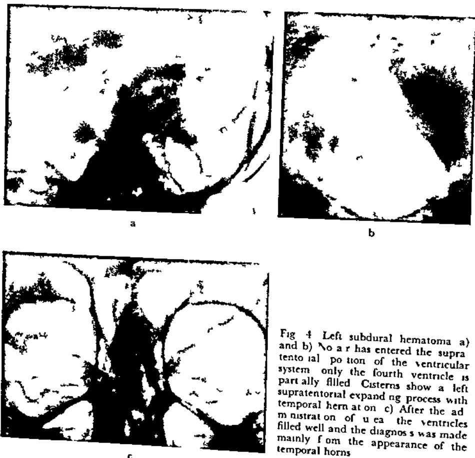


Fig 4 Left subdural hematoma a) and b) No air has entered the supratentorial portion of the ventricular system only the fourth ventricle is partially filled Cisterns show a left supratentorial expanding process with temporal herniation c) After the administration of urea the ventricles filled well and the diagnosis was made mainly from the appearance of the temporal horns

to let any CSF escape whereas in cases of atrophy of the brain or communicating hydrocephalus in which large amounts of air necessarily have to be injected it may be necessary to withdraw a certain amount of CSF in order to avoid too much discomfort to the patient

Late radiographic control In 1959 we (14) proposed the performance of a radiographic control 24 hours after encephalography Since the air in the subarachnoid space is usually absorbed before the air in the ventricles one can so to speak perform a ventriculography without ventricular puncture It is thus possible to obtain better demonstration of some ventricular details which might have been hidden by superimposed air in the subarachnoid spaces or not filled at all at the first examination Continued experience has demonstrated

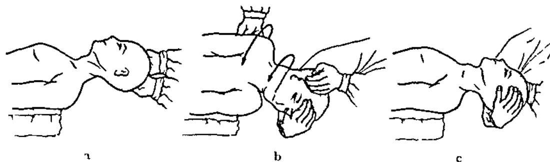


Fig 3 Technique for filling the temporal horn in supine position After (c) the head is placed in the same position as in (a)

lateral views with a horizontal beam in order to demonstrate the anterior portion in its entirety Our technique for filling the temporal horn is as follows after the occipital horns have been studied in the sitting position the shoulder homolateral to the temporal horn which is to be filled is lifted up and the head is slowly turned towards the opposite side and then lowered by accentuating the rotation, in order that the midpoint of the forehead will lie at a lower level than the midpoint of the occiput The head is then rotated back to a forward facing position while still hyperextended, and finally is quickly raised and placed in the correct position for radiography (Fig 3) Experience with our technique has convinced us that it can also provide good demonstration of one temporal horn alone

Modality of gas injection It has recently (3, 15, 16, 17) been suggested, especially by AZAMBUJA's (1) experiments, that a fractionated air study can be tolerated much better if no cerebrospinal fluid (CSF) is removed, or if its removal is minimal The principle of such a technique is based on the observation that the increase of CSF pressure following the injection of air is only of short duration, much shorter in any case than the time necessary for a decreased CSF pressure due to a withdrawal of fluid to return to normal values A transient hypertension in the subarachnoid space is supposed to be less dangerous than a prolonged hypotension We have been using this technique for a fairly long time We have not found differences as striking as those reported by other authors, but this technique seems to be useful mainly to prevent late complications Even the original technique of LINDGREN (5, 7) has always been a benign procedure in our hands Injection of more air than the amount of CSF withdrawn has always been a basic rule in fractional encephalography (9) In a case of posterior fossa tumour with increased intracranial pressure in which only a small amount of air is necessary it will be strictly contraindicated

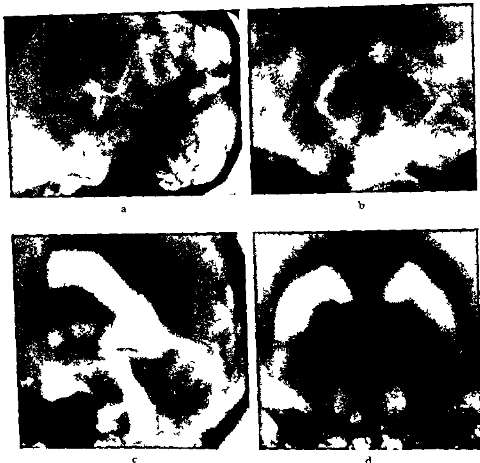


Fig 6 Unv ified br in stem tumour A r does not enter the ventricular system (only the post rior pa t of the th rd ve tr cle i very poo l fill d) n sp te of admini trat on of urea (a) and (b) How ever the d agnosis of pontine tumour was eas ly made on the ba s of the d stort on of the cisterns f the bra n stem It wa anatom cally verified by a entriculography (c) and (d) made at the urgeon r quest

might be caused by several factors and aggravated by the sitting position The blood pressure is measured in the sitting position just before the lumbar puncture and compared with the patient s usual pressure It is important that the blood pressure at the time of the examination should not be significantly lower than the usual pressure If it is lower it must be increased before the examination is begun The blood pressure is also controlled at the end of the examination in the sitting position at the end of the whole examination and every time it is considered necessary In the presence of any untoward reaction

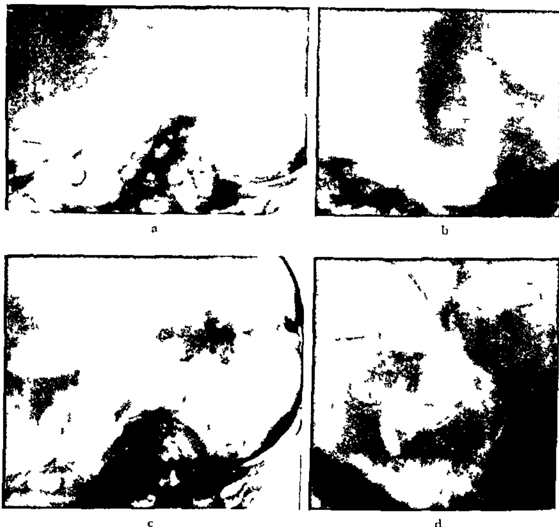


Fig. 5. Left sided medulloblastoma invading the fourth ventricle. No gas enters the ventricular system. Pontine cistern irregularly filled and left cerebello pontine angle cistern not filled (a) and (b). After urea administration the ventricular system filled perfectly. The aqueduct is dilated (c) and there is a filling defect in the fourth ventricle which is also dilated (d).

that 24 hours is too long an interval and we now routinely take control films of our patients about 6 hours after the examination, except in patients in very poor general condition with a clear diagnosis or in patients to be operated upon immediately after the encephalography.

Measuring of the blood pressure. The examination should never be started before the blood pressure has been measured. We are firmly convinced that the great majority of accidents reported as episodes of acute cerebral herniation are instead the results of cerebral ischemia due to arterial hypotension, which



Fig 8 Verified post traumatic left frontal intraventricular hematoma Bilateral angiography was negative the encephalography is diagnostic

is usually performed by the senior members of the team In any case we try to avoid general anesthesia as much as possible and tend to consider it contra indicated in tumours of the posterior fossa and brain stem The only three serious accidents (two of which were fatalities) observed after encephalography were in patients under general anesthesia (These patients however were in poor general condition before the examination) It should be remembered that general anesthesia both depresses the bulbar centers especially the respiratory ones, and increases the CSF pressure

Urea technique At the time of my monograph one main problem remained to be solved the diagnosis of those supratentorial tumours in which because of the cerebral edema no air entered the supratentorial portion of the ventricular system The use of a perfusion of urea solution in encephalography was suggested by ENGESET & HAUGE (2) Independently of their publication we had also started to use urea employing another technique which in our opin ion is more suitable to the principles of encephalography (12 13) We consider the use of urea to be a giant step forward towards a more accurate encephalo graphic diagnosis (Fig 4) When the present paper was being prepared the urea technique had been used in 22 cases of supratentorial space occupying lesions only in 4 of them was there failure of ventricular filling after the urea administration (a deep central tumour a suspected metastatic tumour which could not be verified either at surgery or at autopsy a case of radiologically verified multiple metastases with suspected cerebellar metastases and a parie tal glioma which at surgery did not seem to invade the deep midline structures or the upper brain stem the latter case was the only one in which we could not clearly explain the lack of success)

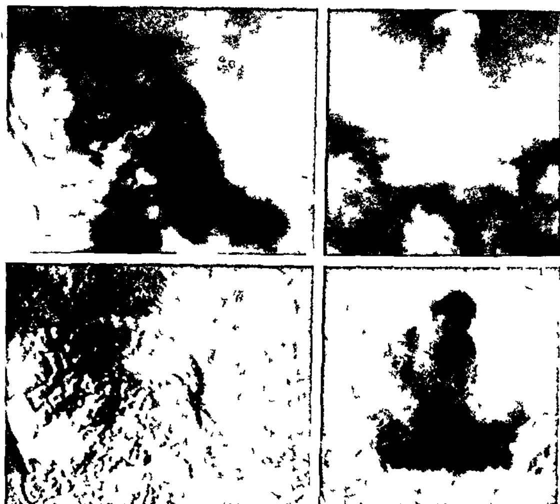


Fig 7 Subtraction in a case of negative encephalography The fluid level in the great cistern is much better outlined

we have often observed a sudden decrease in the arterial pressure which might explain other vegetative troubles such as profuse sweating and coldness of the skin Usually these disorders disappear with the return of the blood pressure to the 'normal' limits

General anesthesia A point of paramount importance is whether or not encephalography should be carried out under general anesthesia Our investigations on the variations of CSF pressure during encephalography seem to demonstrate that such variations, especially those between the initial and final pressure, are more 'regular' in those examinations carried out without anesthesia This seems to be even more marked in cases of brain tumour, but I think that it should be borne in mind that in cases of tumour the examination

RESUME

L auteur analyse les principaux aspects de la technique de l encephalographie fractionnée telle qu elle est pratiquée actuellement dans son service

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In cerebellar and fourth ventricle tumours, the study of the cisterns alone can always indicate the site of the lesion in the posterior portion of the posterior fossa but not always its exact localization, i e in a cerebellar hemisphere, or in the midline There is no doubt that greater experience in encephalography with a more profound knowledge of the encephalographic anatomy has greatly improved the diagnosis, but it might still be rather elaborate The urea perfusion technique is useful also in these cases (Fig 5), but sometimes only indirectly If the administration of urea does not influence the filling of the fourth ventricle and aqueduct one might believe that this lack of filling is not due to a compression of these structures from an edematous cerebellar lobe but to their direct involvement by the tumour, which invades and obstructs the normal pathways between the subarachnoid space and the ventricular system

Subtraction The subtraction technique was first suggested by ZIEDZES DES PLANTES (18) We have had only limited experience with it, but it seems as if this technique can be very useful in studying the cisterns around the occipital foramen

Encephalography in vascular accidents Encephalography has proved useful in cases of brain hemorrhage either traumatic or spontaneous, by demonstrating the presence of an intraventricular clot when a bilateral angiography is negative In all patients in whom the angiographic study is negative, one should not hesitate to perform an encephalography even if they are in poor general condition, one is dealing, usually, with subjects under the control of the anesthetists and the examination can be carried out quickly, especially since a complete study is often unnecessary

SUMMARY

The main aspects of the author s technique of fractional encephalography are described With this technique the examination time is shortened and consequently the procedure is safer and better tolerated

ZUSAMMENFASSUNG

Der Verfasser gibt einen Bericht uber seine Technik bei fraktionierter Encephalographie mit welcher die Zeit der Untersuchung verkurzt werden kann und damit besser toleriert wird



F g 1 D latation de la c terne périvermienne sans insufflat on des s llons vermiens (méga c te ne)

Fig ? Ir ag de lobulation impa vermis cerebel'eux postero ıférieur I verm ens antérieurs sont ı suffles et n(



F g 3 Atrophies verm ennes corticales 1 Local ee au culmen 2 Culmen et dé live 3 D ffuse

que ces cas correspondent a une atrophie vermienne sous corticale ı pas partie de la nosographie des atrophies vermiennes proprement d

En dehors de ces cas nous disposons de 22 observations radio recrutees parmı 3 035 pneumostratigraphies sagittales mediane de postérieure qui se divisent en trois groupes

A *Les ima es d atrophie vermienne corticale* Nos 17 observations de c c ıracterisent par une dilatation des sillons vermiens et des citernes ver On reconnait parfaitement l atrophie localisée a l un a plusieurs ou a ble des lobules vermiens Les corrélations radio cliniques permettent guer 3 formes (Fig 3)

CLINIQUE NEUROLOGIQUE (DIRECTEUR: PROFESSEUR F. THIÉBAUT) ET SERVICE CENTRAL DE RADIOLOGIE (DIRECTEUR: PROFESSEUR CH. M. GROS) DU CENTRE HOSPITALIER UNIVERSITAIRE DE STRASBOURG, FRANCE

ATROPHIES DU VERMIS CÉRÉBELLEUX

par

F. Thiébaut, A. Wackenheim, C. Vrousos et M. Subirana

La nosographie des atrophies cérébelleuses est très complexe et peu précise. Les neuro-pathologistes distinguent de nombreuses formes dont certaines n'ont que des caractères microscopiques.

La pratique de l'encéphalographie gazeuse a conduit à des conclusions souvent erronées basées uniquement sur l'accumulation de grande quantité d'air dans la fosse postérieure. La pneumostratigraphie sagittale médiane de la fosse postérieure telle que nous la pratiquons depuis 1958 permet de préciser ces images et de distinguer celles qui correspondent *réellement* à une *réduction* volumétrique du parenchyme vermien, avec dilatation pathologique des sillons. On connaît par contre beaucoup d'observations d'états malformatifs que nous avons décrits ailleurs, à savoir l'image de mégaciterne (Fig. 1) caractérisée par une dilatation de la grande citerne sans représentation des sillons vermiens, l'image de lobulation vermienne imparfaite (Fig. 2) caractérisée par la présence de sillons vermiens antérieurs normaux avec absence de sillons vermiens postérieurs et l'image de cervelet infantile caractérisé par son petit volume et sa morphologie harmonieuse.

Dans ce travail nous n'avons pas tenu compte des dilatations du IVe ventricule qui s'inscrivent dans le cadre d'une dilatation ventriculaire diffuse. Bien



Fig 7 Atrophie vermienne cortico-sous cortic ale de l enfant

B *Les images d atrophie vermienne cortico sous corticale de l adulte* Dans nos 2 cas de ce groupe il existe d une part une dilatation des sillons vermiens et d autre part une nette dilatation du IV ventricule (Fig 7) Un syndrome cérebelleux n existe que dans l un de ces deux cas

C *Les images d atrophie cortico sous corticale de l enfant* (Fig 8) Dans nos trois observations nous relevons une formule pneumostratigraphique tout a fait superposable Les anomalies sont tres caractéristiques et se distinguent nettement de celles de l adulte Il existe en effet

1 Une forte dilatation du IV ventricule dont le toit est arrondi

2 Une dilatation des sillons vermiens cette dilatation quoique nette est toutefois moins accusée que la dilatation du IV ventricule

3 La réduction du parenchyme vermien predomine sur le vermis postero inferieur contrairement aux formes de l adulte qui predominent sur le vermis antero-supérieur Chez l enfant la region floculo nodulo uvulaire est reduite a une mince languette opaque

Cliniquement il existe un syndrome cerebelleux statique cinétique et progressif dans les trois cas

RÉSUMÉ

Les auteurs étudient 22 observations radio-cliniques d atrophie localisée au vermis cerébelleux Grace à leur technique de pneumostratigraphie sagittale médiane de la fosse postérieure ils distinguent 3 grands groupes d images d atrophie vermienne à savoir l atrophie vermienne corticale localisée ou diffuse l atrophie vermienne cortico-sous-corticale de l adulte et l atrophie vermienne cortico-sous-corticale de l enfant Les auteurs étudient ensuite les corrélations radio-cliniques dans ces trois groupes de cas



Fig. 4. Atrophie vermienne corticale localisée au culmen.



Fig. 5. Atrophie vermienne corticale localisée au culmen et déclive.



a



b

Fig. 6. Atrophie vermienne corticale diffuse (a) et cortico sous corticale de l'adulte (b).

1. *Atrophie localisée à un lobule* (7 cas). Cette anomalie relativement fréquente est cliniquement asymptomatique (Fig. 4).

2. *Atrophie vermienne supérieure* (culmen et déclive 5 cas). Elle s'accompagne d'une nette dilatation du sillon transverse antérieur. Ces atrophies (Fig. 5) relativement étendues s'accompagnent ou non d'une symptomatologie clinique de type cérébelleux. Sur nos 5 malades de ce groupe, 3 présentaient un syndrome cérébelleux à prédominance statique.

3. *Atrophie vermienne diffuse* (Fig. 6) caractérisée par une nette dilatation de tous les sillons vermiens (5 cas). *Ces malades présentent tous un syndrome* cérébelleux statique et cinétique.

FROM THE SURGICAL DEPARTMENT II JUTENDO UNIVERSITY SCHOOL OF MEDICINE, HONGO, TOKYO JAPAN

DIAGNOSIS OF INTRACRANIAL HEMORRHAGE USING ULTRASOUND

by

YUICHI ABE KENJI TANAKA TOSHIO WAGAI and KAZUFUMI ITO

Ultrasound has recently been remarkably developed and advanced i various fields especially in industry and at the same time medical applicatio of ultrasound has been acquiring status as a diagnostic and surgical tool

Since 1951 we have been applying the echo method for the diagnosis various intracranial diseases especially brain tumor and the present autho have since 1953 been successful in achieving early diagnosis of intracrani hemorrhage

It is difficult but very important accurately to differentiate hypertensi intracerebral hemorrhage from other forms of stroke in order to decide b tween conservative management or surgical treatment This is especia important since angiography is usually inevitable for the differential diagno of hypertensive intracerebral hemorrhage brain softening and subarachn hemorrhage We have found the ultrasonic echo method to be more adva tageous for this purpose than the ordinary neurologic examination Thi especially true as the technique is quick and easily performed without harm the patient

SUMMARY

Twenty two radioclinically established cases of atrophy of the vermis cerebelli have been studied by a special technique of sagittal median stratigraphy of the posterior fossa It was possible to distinguish three main groups cortical atrophy either localised or diffuse cortico-subcortical atrophy in adults and cortico subcortical atrophy in children Radioclinical correlations between these three groups were also studied

ZUSAMMENFASSUNG

Es wurden 22 rontgenologisch und klinisch gesicherte Falle von Atrophie des vermis cerebelli mittels einer Spezialtechnik von sagittaler medianer Stratigraphie der Hinteren Schadelgrube studiert Es war möglich drei Hauptgruppen zu unterscheiden Cortikale Atrophie lokal oder diffus corticosubcorticale Atrophie bei Erwachsenen und cortico-subcorticale Atrophie bei Kindern Es wurden ebenfalls die Korrelationen zwischen diesen drei Gruppen studiert

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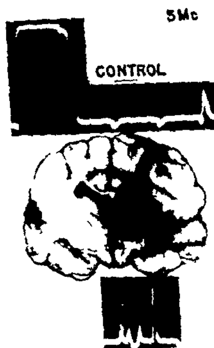


Fig 2 *Intracerebral h matoma* in a cat Con t nuous sharp echo

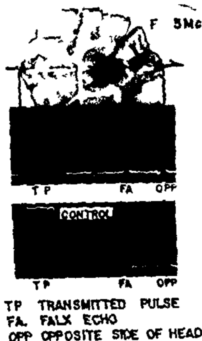


Fig 3 Brain softeni g in a cat No echo

Extracerebral hematomas were made by injecting blood coagulum into the epi and subdural space of a cat The echo from the hematoma can be detected by using ultrasound at 5 megacycles per second On the other hand in the case of an intracerebral hematoma made by injecting 0 1 or 5 ml of blood coagulum into the hemisphere of a cat s brain the echo from the hematoma shows a characteristic pattern which consists of continuous sharp echo similar to hyper tensive intracerebral hemorrhage (Fig 2) On the contrary in the case of brain softening made by injecting 5 % agar into the internal carotid artery of the cat these echoes were not observed (Fig 3)

In addition to the analysis of the echoes the measurements of ultrasonic attenuation in brain tissue are very important For example it is found clinically that patients who are in the stage of brain edema have the highest level of ultrasonic attenuation For detection of ultrasonic attenuation in brain tissue and blood the heat production in these samples due to irradiation of ultrasound was measured It was found that the ultrasonic attenuation in blood was smaller than in meningioma The transmission and reflection method

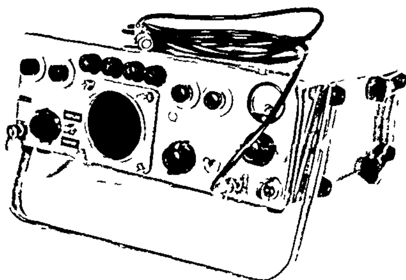


Fig 1 Ultrasonic apparatus from Japan Radio Co Aloka model SSD 2

Apparatus The standard ultrasonic apparatus (Aloka model SSD 2, Japan Radio Co) was used with an adapted camera (Fig 1) The echoes were displayed on the Braun tube by A scope indication Being portable, the instrument may be carried to the bedside and plugged into the main electrical supply

The transducers used were barium titanate (1 and 2 25 megacycle) and piezoelectric quartz crystal (5 and 10 megacycle) The following types of probes were used 1 and 2 5 megacycle 10 mm in diameter, for the examination through the intact skull, 5 and 10 megacycle 10 mm in diameter for direct application on the brain

Experimental studies

The acoustic velocity for brain tissue was found to be 1 460 m/sec, and for blood 1 560 m/sec Fresh human blood and brain tissue show an acoustic impedance of 1 660 $g/cm^2/sec$ and 1 510 $g/cm^2/sec$ respectively The velocity in glioma tissue is 1 600—1 660 m/sec Thus it is theoretically possible that the border between brain tissue and blood will cause an acoustic reflection This possibility could also be demonstrated in animal experiments

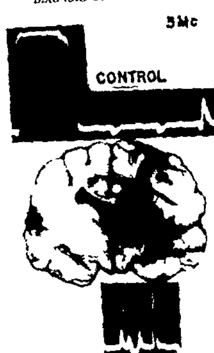


Fig 2 Intracerebral hematoma in a cat Continuous sharp echo

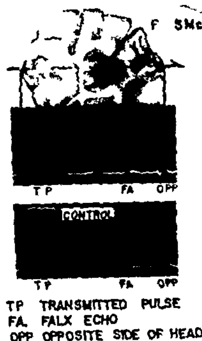


Fig 3 Brain softening in a cat No echo

Extracerebral hematomas were made by injecting blood coagulum *into the* epi and subdural space of a cat The echo from the hematoma can be detected by using *ultrasound* at 5 megacycles per second On the other hand in the case of an intracerebral *hematoma* made by injecting 0 1 or 5 ml of blood coagulum into the hemisphere of a cat's brain the echo from the hematoma shows a characteristic pattern which consists of continuous sharp echo similar to hypertensive intracerebral hemorrhage (*Fig 2*) *On* the contrary in the case of brain softening made by *injecting* 5 % *agar into* the internal carotid artery of the cat these echoes were not observed (Fig 3)

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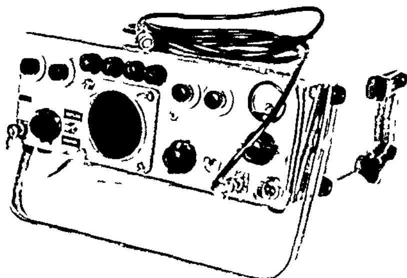


Fig. 1. Ultrasonic apparatus from Japan Radio Co. Aloka model SSD 2

Apparatus. The standard ultrasonic apparatus (Aloka model SSD 2, Japan Radio Co) was used with an adapted camera (Fig. 1). The echoes were displayed on the Braun tube by A scope indication. Being portable, the instrument may be carried to the bedside and plugged into the main electrical supply.

The transducers used were barium titanate (1 and 2.25 megacycle) and piezoelectric quartz crystal (5 and 10 megacycle). The following types of probes were used: 1 and 2.5 megacycle 10 mm in diameter, for the examination through the intact skull, 5 and 10 megacycle 10 mm in diameter for direct application on the brain.

Experimental studies

The acoustic velocity for brain tissue was found to be 1 160 m/sec, and for blood 1 560 m/sec. Fresh human blood and brain tissue show an acoustic impedance of 1 660 g/cm²/sec and 1 510 g/cm²/sec respectively. The velocity in glioma tissue is 1 600—1 660 m/sec. Thus it is theoretically possible that the border between brain tissue and blood will cause an acoustic reflection. This possibility could also be demonstrated in animal experiments.

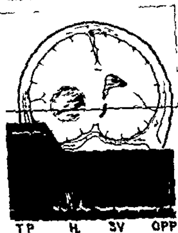


Fig 6 Case 2 I tra cerebral hemor rhage Irregularly grouped echoes H = H matoma echoes



Fig 7 [Ca e 3 Brain softening N ab normal echoes

of a shift of the third ventricle is useful for screening while the detection of the hematoma echo is necessary for the diagnosis of intracranial hematoma The sharp bottom echo of the hematoma is detected either by the examination from the same side as the lesion, or from the opposite side of the lesion (Fig 4) The ultrasonic attenuation increases on the hematoma side as compared with the normal side of the head

Case 1 A 58-year-old male who had had a head injury four months prior to admission was admitted in a state of coma with right hem plegia At the neurologic examination the deep reflexes on the right were exaggerated and Babinski s sign was positive on the right side Right hemiplegia and b lateral choked optic di cs were noted

At the ultrasonic examination through the right temporal region the third ventricle echo was shift d to the right and the sharp echo from the hematoma was observed just before the opposite side of the head (Fig 5) Left carotid angiography showed displacement of the peri callosal artery to the right side and an avascular area in the left parieto-temporal region A subdural hematoma was evacuated from the left parieto-temporal region

Ultrasonic examination was performed on 369 cases with head injuries, and out of 38 cases of extracerebral hematoma 35 cases were correctly diagnosed (26 out of 27 subdural hematomas both cases of subdural hygroma and 7 out of 9 epidural hematomas)

In the postoperative follow up observation of these cases the return of the displaced third ventricle echo to the normal position can be observed It

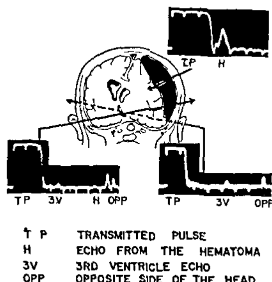


Fig 4 Extracerebral hematoma The sharp bottom echo of the hematoma was detected by examination from both sides

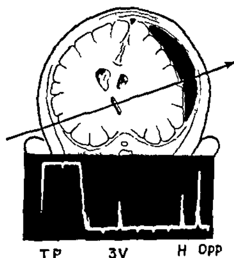


Fig 5 Case 1 Extracerebral hematoma

of ultrasonic pulse was used for the detection of ultrasound attenuation in the clinical studies

The experimental studies of the characteristics of hematoma echoes were performed as follows

The samples given below were put into a beaker 4 cm in diameter 1) Degased water, 2) blood with heparin, 3) blood with brain fragments 4) blood containing heparin and brain fragments, 5) blood containing coagula and brain fragments The samples were then examined with a transducer of 5 megacycles, 10 mm in diameter

Except for the degased water continuous sharp echoes from the samples, especially in the case of blood including brain fragments, were observed On the other hand, no special echoes were observed in the case of degased water It was clear, experimentally, that the echoes from the hematoma were influenced by brain fragments included in the hematoma

Clinical studies

Diagnosis of extracerebral hematoma

A shift of the third ventricle echo does not always prove the presence of a hematoma because the shift of this echo can also be caused by unilateral edema, hygroma and tumor Furthermore, in the case of bilateral hematoma, a shift of the third ventricle echo could not be observed Thus, the observation

Examination of brain softening

Case 3 A 66-year-old male was admitted with delirium and mental change Neurologic examination revealed a hypnotic male with disorientation emotional instability and nuchal rigidity The deep reflexes were exaggerated and Hoffman s sign was positive on the left side Lumbar puncture revealed an initial pressure of 150 mm of water with xanthochromia.

At the ultrasonic examination abnormal echoes were not disclosed in either of the frontal regions and the third ventricle echo was not displaced The attenuation of ultrasonic energy in brain tissue was normal (Fig 7) Multiple softening in the frontal lobe was disclosed at autopsy

In the case of brain softening and subarachnoid hemorrhage neither an abnormal echo nor a shift of the third ventricle echo were observed, these conditions show a normal level of ultrasonic attenuation in most cases

Ultrasonic examination was performed in 108 cases with so-called apoplexy including hypertensive intracerebral hemorrhage brain softening and subarachnoid hemorrhage The ultrasonic diagnosis was intracranial hemorrhage in 41 patients brain softening in 60 and subarachnoid hemorrhage in 7 (see tabulation below) In the patients with intracerebral hemorrhage the ultrasonic echogram showed clear evidence of the lesion

	Ultrasonic diagnosis	Clinical diagnosis
Subarachnoid hemorrhage	7	8
Brain softening	60	57
Cerebral hemorrhage	41	31
So-called apoplexy		12

The ultrasonic characteristics of hematoma echoes were examined with a transducer of 5 megacycles/sec on the dura mater The hematoma echo reveals a characteristic continuous sharp echo while a tumor echo is observed as a continuous irregular echo

The writers confirmed clinically that the hematoma echo is basically different from the tumor echo (Fig 8)

Conclusions

In patients with extracerebral hematoma a shift of the third ventricle echo to the opposite side of the lesion is observed together with a hematoma echo Usually the sharp bottom echo of the hematoma is detected by the examination from the opposite side of the lesion

In intracerebral hemorrhage an abnormal echo from the hemorrhage is observed as a characteristic continuous sharp echo and can be differentiated from tumor echoes which are characterized by continuous irregular echoes

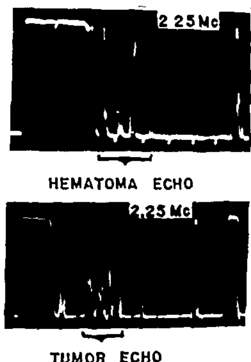


Fig 8 Difference between hematoma and tumor echo

took 1 to 4 weeks after the evacuation of the extracerebral hematoma for the echo to return to normal Thus, a continuous observation of the third ventricle echo is very useful for the postoperative management of intracranial hematoma

Diagnosis of intracerebral haemorrhage

Case 2 A 52 year old male was admitted in a state of semi coma with right hemiplegia He had had sudden attacks of unconsciousness thereafter vomiting had begun At the same time he noted weakness in the right arm and leg which was slowly progressing At the neurologic examination right hemiplegia and exaggeration of the deep tendon reflexes on the right was noted and Babinski s sign was positive bilaterally Lumbar puncture revealed an initial pressure of 200 mm of water and the cerebrospinal fluid was xanthochromic

At the ultrasonic examination the third ventricle echo was shifted to the right about 10 mm and the ultrasonic attenuation was increased on the left side The abnormal echoes were detected 3 to 6 cm inside the left fronto temporal region There were irregularly grouped echoes (Fig 6) Under local anesthesia the blood coagulum was evacuated in the fronto temporal region

The present writers thus confirmed that the ultrasonic findings of intracerebral hemorrhage were as follows a) detection of an intracerebral abnormal echo, 2) shift of the third ventricle echo, (3) increase of ultrasonic attenuation

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In brain softening and subarachnoid hemorrhage on the other hand, an abnormal echo and a shift of the third ventricle is not observed

In addition to the analysis of the echoes, observation of the degree of ultrasonic attenuation in the brain, especially on the hematoma side, is very important From this standpoint, extra and intracerebral hematomas are characterized by an increase in the ultrasonic attenuation Brain softening and subarachnoid hemorrhage, on the other hand, have a normal level of ultrasonic attenuation in most cases

The ultrasonic examination is useful for quick diagnosis of extracerebral hematoma in patients with head injury and for the differential diagnosis of apoplexy

SUMMARY

The clinical value of ultrasonic diagnosis in intracranial hemorrhage is discussed The ultrasound equipment used was the Aloka model SSD 2 manufactured by the Japan Radio Co Ultrasonic examination is useful for a rapid diagnosis of extracerebral hematoma in patients with head injury and in the differential diagnosis from apoplexy

ZUSAMMENFASSUNG

Es wird über den klinischen Wert der Ultraschalldiagnose bei intrakraniellen Blutungen berichtet Es kam das Aloka Modell SSD 2 hergestellt von der Japan Radio Co zur Verwendung Ultraschalluntersuchung ist wertvoll fur die rasche Diagnosestellung von extracerebralen Hämatomen nach Schädelverletzungen und in der Differentialdiagnose gegenuber Apoplexie

RÉSUMÉ

Les auteurs montrent l intérêt clinique de l examen par les ultrasons dans les hémorragies intracraniennes L appareil utilisé est le modèle Aloka SSD 2 fabriqué par la Japan Radio Co L examen par les ultrasons est utile pour le diagnostic rapide des hématomes extracérébraux chez les traumatisés craniens et pour le diagnostic différentiel avec l apoplexie

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Fig. 1 Method of examination showing mechanical scanning bridge which holds and moves the transducer on the patient's head The technician guides the direction of the transducer to permit good acoustical contact during the entire scanning period

The purpose of this paper is to illustrate our techniques and early experience with a simple 'B' scanning in patients with intracranial masses

Description of the system The technical details are not within the scope of this paper The system involves the production of an ultrasonic pulse (1 to 2 mc/sec frequency) from a piezoelectric crystal which is transmitted through the skull by a transducer A water or glycerine coupling medium between the transducer probe and the skull provides acoustic contact The reflected echoes are received by the same transducer and are then amplified electronically and displayed on the cathode ray tube as many bright spots

The A scan presents a one dimensional evaluation of echoes which can be used to determine the position of the interfaces of tissue structures such as the midline of the brain

For B scanning the transducer is coupled to a mechanical scanning bridge which moves it over the surface of the skull (Fig 1) The scanning bridge also moves the point of the cathode ray tube trace over a path which is linked to the movement of the transducer The echo signals received by the transducer and displayed on the cathode ray tube are intensity modulated so that the echoes appear on the oscilloscope face as spots whose brightness is proportional to echo strength rather than height of pulse The echoes are recorded in their proper geometrical relationship by making a photographic record of the cathode ray tube during the entire scanning

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'B' SCAN ENCEPHALOGRAPHY

by

B D ADAPON, N E CHASE, I I KRICHEFF and A F BATTISTA

The use of ultrasonic acoustic waves to demonstrate the structure of biological tissues is well known (21) The principles are roughly similar to those of marine sonar equipment used for detection of submarines

WILD delineated the structure of bowel segments by means of ultrasound in 1950 (20) Since then, various modifications of the pulse echo have been used to delineate normal and abnormal body structures including the localization of gall stones, soft tissue tumors, ocular foreign bodies, renal, hepatic, uterine, breast and pelvic tumors (2, 4, 8, 9, 10, 11, 17, 22) These examinations required the immersion of the parts being studied in a fluid containing chamber or the use of a water containing plastic bag for the adequate functioning of the system HOLMES & HOWRY (9) using elaborate equipment have constructed a compound circular 'B scanning system that gives differential echo images of the neck, extremities and abdominal structures

In the brain, the application of the ultrasound pulse for diagnosis has been limited to the localization of the midline structures (1, 5, 7, 13, 15) This 'A' scanning has also been extended by other investigators to the study of abnormal pulses by intracranial masses such as subdural hematomas and ventricular size (3, 16, 18, 19) TANAKA, KIKUCHI and others (6, 14), obtained differential echo images in brain masses during operation and in pathological specimens



Fig 3 Normal scans a) Simple A scan for detection of midline structures obtained by conventional method with stationary transducer (1) Midline (3) skull tables b) Normal B scan obtained with moving transducer (see fig 2) demonstrates cross section or tomogram of brain at level of scanning (1) Midline echo (2) lateral ventricles (choroid plexus) (3) skull tables (4) level of external auditory meatus

60 were proven to have intracranial expansive lesions and the remainder (67) were diagnostically negative after all investigations

The classification and location of the intracranial expansive lesions (60 cases) are given below

	Not demonstrated	Demonstrated Indirect	Direct
Subdural hematomas	5	5	1
Intracerebral hematomas	1	4	
Posterior fossa tumors	1		1
Hypophyseal tumors	1	1	2
Multiple masses	2	3	2
Solitary cerebral tumors			
Anterior or frontal		4	1
Suprasylvian	4	3	2
Infrasylvian		3	3
Retrosylvian	1		1
Thalamic and deep frontal		1	3
Hydrocephalus	1		4
Totals	16 (26 6)	24 (40)	20 (33 4)

There were 11 subdural hematomas 5 intracerebral hematomas 5 meningeomas 21 gliomas 7 multiple masses, 4 hypophyseal tumors and 2 infratentorial lesions

The intracranial lesions were demonstrated by B scan tomography either directly or indirectly in 44 patients (73 4 %) The B scan failed to demonstrate a mass in 16 (26 6 %) although all of these cases had displaced midline

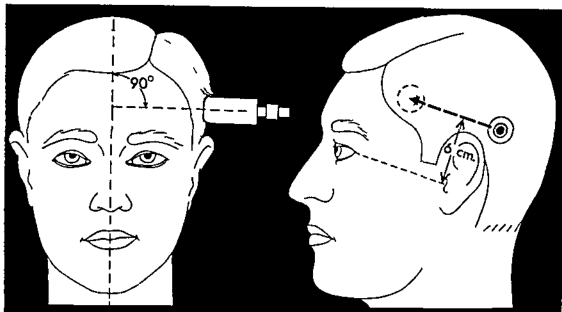


Fig. 2. Diagrammatic sketch of transducer pathway on patient's head. Reference mark at level of external auditory meatus.

Method of examination. The patient is placed in the decubitus position and the transducer probe is applied along a line drawn on the occipitotemporal frontal region 6 cm above the canthomeatal line (Fig. 2). The transducer is moved from posterior to anterior and the tracing is marked at the level of the external auditory meatus. The speed of the probe is usually 2.5 cm/sec, which is regulated by the motorized transducer holder. The direction in which the transducer is aimed may be adjusted up to 30° from the vertical. This aids in obtaining a proper beam entrance and good acoustical contact along irregular contours.

Paired tracings are obtained on both sides of the skull and the tracings are photographed with the Polaroid Land Camera (Fig. 3).

In some cases the transducer path is 5 or 7 cm from the canthomeatal line depending on the presumed level of tumor clinically.

Clinical material and results

A total of 127 patients were studied. There were 41 females and 86 males with ages from 1 month to 80 years with a mean age of 40.5 years. All patients had conventional neuroradiologic diagnostic procedures (encephalography or cerebral angiography) and/or surgical exploration or autopsy examination,



a

Fig 7 a) Acute subdural hematoma in right temporo-parietal frontal convexity in a 38 year-old male b) A scan Midline shift right to left 7 mm c) B scan Absence of echoes in the right frontotemporal convexity displacement of leptomeninges by subdural collection



b



c

echoes in the A scan There were five false positives 2 had the appearance of subdural hematomas and 3 had displaced lateral echoes on one side only These cases proved to be normal except for one with diffuse cerebral atrophy

Echographic findings The space occupying lesions may be detected by direct sonic demonstration of the mass (23) or by indirect signs The former may occur in two ways

1 The lesion may reflect more sound than the normal tissue echo background (Fig 4) *In addition abnormally directed echoes may be observed* We believe that the abnormal cluster of echoes is produced by the multiple tissue interfaces of the mass with polarity that varies from the surrounding normal brain tissue

2 Other lesions reflect less sound than the normal tissue background and may appear as a hole or less dense area of echoes (Fig 5)

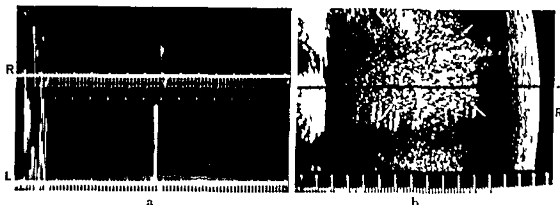


Fig 4 Direct positive demonstration on a 49 year old male with large posterior frontal parietal glioblastoma a) A scan Midline shift right to left 3 mm b) B scan Abnormal cluster of echoes with different echo polarity in region of tumor

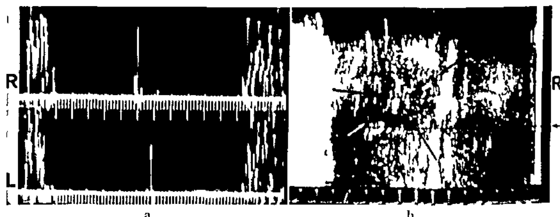


Fig 5 Direct negative demonstration of left deep fronto thalamic glioblastomas in a 37 year old female a) A scan Midline shift left to right 5 mm b) B scan Spherical area of tumor with displaced strong midline echo

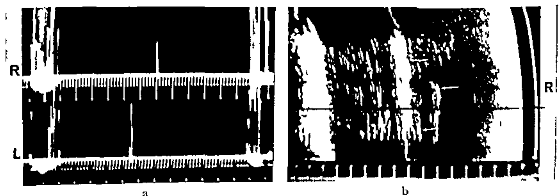


Fig 6 Indirect demonstration of *deep temporo thalamic intracerebral clot in a 40 year old male* a) A scan Midline shift right to left 7 5 mm b) B scan Lateral and midline echoes markedly displaced towards left



Fig 9 B scan tomogram superimposed on horizontal cross-section of the brain specimen scanned demonstrating the various midline structures that may give rise to the midline echo Strong midline echoes from anterior and posterior portions of interhemispheric fissure the third ventricle and fornix septum pellucidum strong echoes from the insula

Discussion

The oscillographic display of reflected echoes from tissue interfaces depends upon the acoustic impedance of the reflecting substance and the angle of incidence of the sound beam (12) Tissue interfaces with large changes in acoustic impedance may reflect enough of a differential echo to permit these interfaces to be identified

Also following the law of reflection the greatest amount of ultrasonic echoes will be picked up when the sound strikes tissue interfaces at right angles A differential echo pattern will thus be shown when the abnormal masses are disposed perpendicular to the ultrasound beam Unfortunately the axes of the different tumor masses studied were not always perpendicular to the main axis of the transducer beam because at the present time the transducer pathway is limited to 1 or 2 levels of cross section This is due to the difficulty in obtaining good acoustic linkage at higher or lower levels on the skull

For example among the gliomas the frontal and low suprasylvian masses were picked up readily The main axis of the tumor bulk in these locations is



Fig 8 From infant with hydrocephalus secondary to aqueductal stenosis a) A scan Midline shift left to right 4 mm b) B scan Huge lateral ventricles seen left greater than right

Indirectly, the tumor may be demonstrated by the displacement or obliteration of normal tissue structures (Fig 6) Echoes may be either the strong midline echo shifted to one side or the more laterally placed echoes from the insula being absent or shifted medially or laterally

In cases with subdural hematoma (see Fig 7) the displacements of the leptomeninges by an accumulation of clot may be demonstrated Unfortunately, the immediate 8 to 10 mm beneath the inner table of the ipsilateral side of the skull is masked by the main bang of echoes arising from the cranial vault For this reason only subdural hematomas over 1 cm in thickness could be demonstrated

Enlarged lateral ventricles were noted directly in 5 patients with hydrocephalus The echo failed to demonstrate enlarged ventricles in one case The reason for this is not clear The enlarged ventricles are seen as areas of echo lack in an otherwise normal tissue background (Fig 8) The lateral echoes are also correspondingly displaced

Source of normal echoes Normal formalinized brain specimens were scanned with techniques as nearly similar to those used in living subjects as possible In Fig 9, the resulting B scan is superimposed on the horizontal cross section of the brain at the level of scanning Strong echoes are seen reflected from the midline structures as well as the insula and portions of the lateral ventricles It can be seen that the strong and constant midline echo originates from different structures in the midline, normally the anterior and posterior portions of the interhemispheric fissure the third ventricle and the septum pellucidum Thus, the echo source can vary according to the placement of the transducer probe and the shape of the skull

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approximately perpendicular to the transducer pathway The parasagittal and high convexity tumors as well as the low lying temporal masses were not demonstrated because they were centered above or below the line of scan These masses are only seen indirectly i e in the degree they displace normal tissues

Acknowledgements

This work was supported in part by the New York City Health Research Council Contract No U 1175 and in part by the National Institutes of Health (National Institute for Neurological Diseases and Blindness) Contract No 5433 01 It would not have been possible without the hard work and cooperation of Mr Ralph Majoral and Mr Ramon Santana

SUMMARY

Sixty patients with various types of intracranial masses were subjected to A and B scanning Forty four of them showed abnormal echographic findings on the B scan either directly or indirectly and in 16 the lesion could not be observed by B scanning although the midline displacement was noted in the A scan

ZUSAMMENFASSUNG

Sechzig Patienten mit verschiedenen Typen von intrakraniellen Tumoren wurden mittels A und B Scintillographie untersucht Vierzig davon zeigten im B Scintillogramm einen normalen echographischen Befund entweder direkt oder indirekt Bei 16 Patienten konnte keine Veränderung im B Scintillogramm gefunden werden obwohl eine Seitenverschiebung *im A Scintillogramm vorhanden war*

RÉSUMÉ

Soixante malades atteints de diverses tumeurs intracraniennes ont été examinés par les explorations A et B Quarante quatre d entre eux ont présenté des signes échographiques anormaux sur l examen B directement ou indirectement et seize n ont pas présenté de signe de leur lésion sur l examen B bien que l examen A montrait un déplacement de la ligne médiane

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Fig 1 Position of patient and probes for recording at start of injection

of the material as it passes through the torcula In the more recent observations the two probes have been positioned for a series of three injections (Fig 2b) The standard positions are 1) The timing of the event which is obtained in the standard carotid inion position 2) The second recording is made with one probe centered over the midline at a fixed distance anterior to the inion 3) The final measurement is made over the carotid on a 3 cm center so that it is possible to obtain a carotid input velocity and a jugular output velocity It is necessary to use more than one injection because of the inability to obtain more probes at present We are able to obtain through this group of curves an appreciation of average velocities and to relate these to specific times in the entire event

Results

If velocity measurements are made in a normotensive individual having only minimal neurological deficit no gross cerebral vascular disease and no space occupying mass we are able to obtain a series of points which are velocities which can be plotted versus time A straight line relationship exists which indicates that there is a velocity gradient from artery, to sinus to vein in decreasing order (Fig 3a) This order holds as long as a process does not favor the development of shunts If a patient has arterial hypertension the input velocity is greater and the gradient is much steeper (Fig 3b) This has been true during several observations in hypertensive patients

In the presence of increased intracranial pressure the relationships lose their linearity and there is an arrival of bolus at the inion ahead of the anterior

FROM THE NEUROSURGICAL SECTION, U S VETERANS ADMINISTRATION HOSPITAL,
WADSWORTH, KANSAS, U S A

CEREBRAL BLOOD FLOW MEASURED WITH RADIOACTIVE ISOTOPES

by

ROBERT L BELL

For several years, we have been interested in observing changes in the shape of a radioactive bolus as it has passed from the carotid arterial circulation through the brain, and its alteration in configuration at the venous output These observations have been considered a dynamic indicator of the status of the cerebral circulation

Instrumentation Basically, the cerebral circulation has two carotid inputs and two vertebral inputs, whereas the venous outputs are numerous In our first efforts to observe the bolus, we recorded only at the arterial input over the carotid artery and the venous output at the inion The patient (Fig 1) is positioned so that 0 2 ml of RISA can be injected through the carotid artery after the completion of angiography The scintillation probes are positioned so that the observations are made at the desired anatomical sites The recording instruments process the data and from these we are able to obtain records for evaluation of the events per unit of time In Fig 2a, the top line of the recording shows an input spike, the second rise is the output slug as it passes in the jugular vein adjacent to the carotid artery The lower tracing indicates the distribution

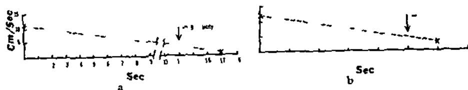


Fig 4 Velocity gradient in a patient with increased intracranial pressure (a) and in a patient with a glioma (b)

In the presence of a tumor (Fig 4b) the shunts via a deep glioma permit blood to enter the deeper venous circulation and the torcula in advance of the sagittal sinus It might be said that an asynchronism develops where a negative velocity is assigned and because of incomplete shunting there is a prolonged discharge pattern through the jugular vein In some patients we have observed pulsatile discharge over the jugular output

Discussion

Like all physiological measurements no two observations are the same It was hoped at the start that the simpler records could be analyzed in the same fashion as a cardiac output curve This would lead to the application of an analogous technique which would give answers to problems of cerebral blood flow Because of complex curves and variability between cases calculations would be prohibitive and would necessitate computer techniques However from these studies we have gained knowledge in conjunction with angiography which indicates that there are considerable alterations in the circulation time and variations contributed by vascular shunts If large numbers of patients are studied with these *techniques* certain similarities may be observed in the tracings

Most radiologists know the major anastomotic pathways of the circulation but few realize how critical *these shunts* become when there is abnormal intracranial pressure caused by space occupying lesions By the application of more probes at strategic locations and the use of shorter half life isotopes more measurements can be obtained from each patient We would advocate evaluation of both hemispheres simultaneously in order to detect leaks through the opposite jugular vein

Of theoretical consideration would be how to improve the relationships Conceivably by altering the cardiac output the gradients could be readjusted However this would not induce blood to flow in the regular gradient in presence of increased intracranial pressure If however a decompression were

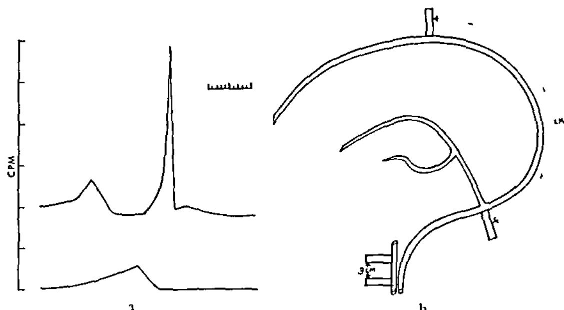


Fig 2 a) Tracing of a recording showing on top line the input arterial spike Later there is an attenuation and a reappearance of material in the jugular vein Bottom line reveals material as it flows through inion Time markers 1 sec Vertical scale count/minute b) Diagram of position of probes for velocity measurements

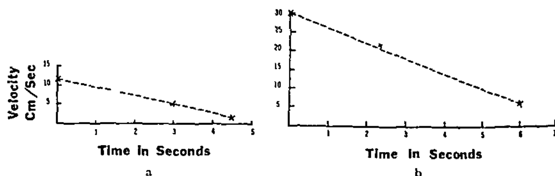


Fig 3 Velocity gradient in a normotensive patient (a) and in a hypertensive patient (b)

sinus measurement (Fig 1a) This means that we must either consider the velocity as negative or negative in relation to time Both of these concepts are hard to resolve unless one remembers that shunts may channel material to the inion before the material can travel by way of the sagittal sinus, i e, there is absence of the configuration of a normal velocity gradient This particular patient had generalized cerebral swelling with impairment of the circulation of the veins emptying into the sagittal sinus and apparently faster emptying through the deep venous midline circulation All of these factors were evaluated and correlated with the concomitant angiography

FROM THE DEPARTMENT OF RADIOLOGY NEUROLOGICAL INSTITUTE, COLUMBIA PRESBYTERIAN MEDICAL CENTER NEW YORK, U S A

ULTRASOUND CROSS SECTIONAL PICTURES OF THE HEAD

by

RAY A BRINKER and JUAN M TAVERAS

Ultrasound has played an increasingly important role in neurological diagnosis since its first application by LEKSELL in 1956 Originally the equipment used was borrowed from the engineering field of nondestructive testing and was relatively crude in its application for biological work Gradually over the intervening years more sophisticated equipment both from the mechanical and electronic standpoints has been developed and this has led to improved methodology for its use

Midline echoencephalography has now become a well established method for diagnosis In working with classical midline echoencephalography equipment many workers (CARLIN 1960 GORDON 1964 JEPPSSON 1961 RICHARDSON 1962) have been intrigued by the number of echoes occurring from ultrasonic interfaces other than the midline If a method could be found to record these interfaces, cross sectional anatomical pictures of the brain could be made To this end the procedures and equipment described in this paper were developed

History

The first attempt to define intracranial anatomy in pictoral form was described by DUSSIK et coll (1947) and later by BALLENTINE (1950) Unfortu

afforded, it might be possible to show a re establishment of the normal gradient Indeed this may be the case in a decompressive procedure, such as removal of the mass or the performance of a lobectomy

Conclusions

It is possible to demonstrate a linear velocity time relationship between arterial input, sagittal sinus and venous output in the patient who does not have increased intracranial pressure In those having increased intracranial pressure, there is an alteration of the velocity occurring in the region of the superior sagittal sinus and its tributaries In this instance, either sinusoids in the tumor bed, or well known venous shunts, alter the velocities observed at the sagittal sinus/inion outflow and favor an inversion of the normal relationships

SUMMARY

By proper placement of scintillation probes vascular velocity gradients can be measured in the central nervous system Full exploration of techniques could permit evaluation of blood *flow including shunts*

ZUSAMMENFASSUNG

Mittels geeigneter Anbringung von Scintillationssonden kann der Gradient der Blutstromgeschwindigkeit im ZNS gemessen werden Bei voller Ausnutzung der Technik kann das Ausmass der Blutzirkulation inklusive shunts bestimmt werden

RÉSUMÉ

La mise en place convenable de sondes a scintillations permet de mesurer dans le système nerveux central des gradients de vitesse circulatoire L étude complète de ces techniques pourrait permettre la mesure de débit sanguin y compris dans les shunts

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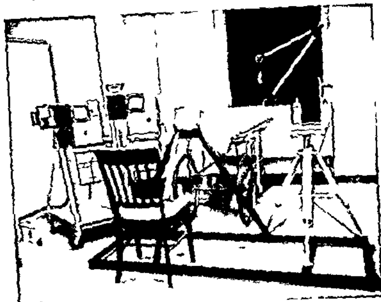


Fig 1 Apparatus used for scanning The patient lies supine on the stretcher *with his head in the holder* and the examiner sits facing the top of the patient's head Scanning frame supported on its tripod to the right oscilloscopes *to the left*

side of the head in a normal subject, and if displaced indicates the *presence* of a mass lesion on the side indicated A transmission trace is then utilized as a check as originally introduced by LITHANDER (*1960*) The accuracy of this method has been determined by many workers (JEPPSSON 1961)

In our equipment (*Porta scan* — Physionics Engineering Inc Longmont Colorado) the transducer is fixed to three rigid arms (Fig 1), which in turn are connected to a movable frame Each arm is connected to this reference frame by fine steel wires Movement of any of these three arms will be accurately recorded on the oscilloscope both in position and direction The mechanical and electronic apparatus is to be discussed in a separate paper

There is a great difference in the relative amplitude of ultrasonic signals returning from the head which is dependent upon the angle of reflection the size of the interface and the difference in the specific acoustic impedance of the interface At present there is no satisfactory method of utilizing the information concerning the amplitude or width of the interface The authors therefore decided to use only the information that an interface is or is not present at some particular point in space For this purpose a video activated pulser has been designed and built This unit will cause a minute dot on the

nately, the transmission method used did not result in meaningful pictures of the intracranial contents, due to varying thickness of the skullbone over the scanned region. This line of investigation was abandoned.

FIRESTONE, in 1945, introduced the pulse echo technique into ultrasound. In this manner ultrasound is sent into the structure under study and echoes are received back from it. This so called echo ranging technique has been developed extensively in industry and is the method applied for present day neurological application as echoencephalography.

DE VIEGLER, in 1963, recorded attempts to make intracranial pictures utilizing water path and contact scanning. His pioneering work in the field has resulted in some pictorial representations which have not, as yet, been well correlated with the actual position of intracranial structures. TANAKA et coll. (1962) have also done work in the neurological area in attempting to make intracranial pictures.

The technique of compound ultrasound tomography was extensively developed and used by HOWRY et coll. (1956) in parts of the body other than the head. More recent work by HOLMES & HOWRY (1963) and others has further extended this, so that examinations of the kidney and liver are now fairly routine. BAUM & GREENWOOD (1961) have used compound scanning at high frequency ranges to make outstanding cross sectional pictures of the eye.

Equipment

In a classical A scan echoencephalography the transducer is placed in contact with the side of the head at a point approximately above the external auditory canal. The ultrasound energy passes into the head and returns from the region of the posterior third ventricle to the transducer face, after a delay indicated by the speed of sound in the head. This minute returning echo is fed into a preamplifier, amplifier, and is then detected in a wide band video system.

The time base sweep from left to right of the oscilloscope face is adjusted either to the speed of sound in the head or to some known multiple for ease of recording the results. In our equipment the horizontal type base is adjusted to exactly half the speed of ultrasound in the head so that the resultant pictures are minified by half. The time base is amplitude modulated by the reflected energy from the ultrasonic interfaces and causes a deflection on the base of the oscillosope trace. In this manner, by knowing the speed of the time base sweep, the actual distance from the transducer face to the interface under study, in this case the posterior third ventricle, can be ascertained. Obviously, the distance to the posterior third ventricle should be the same from either

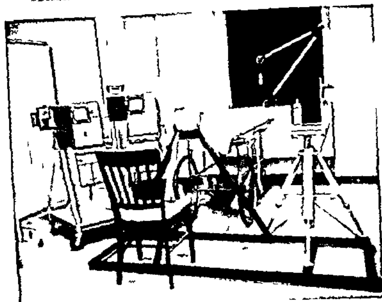
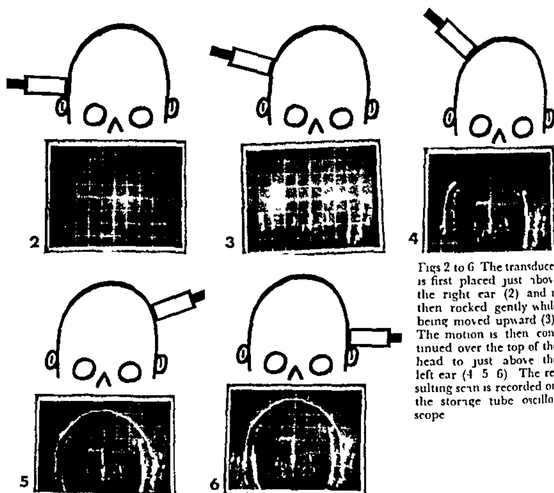


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Figs 2 to 6 The transducer is first placed just above the right ear (2) and is then rocked gently while being moved upward (3) The motion is then continued over the top of the head to just above the left ear (4 5 6) The resulting scan is recorded on the storage tube oscilloscope

face of the read out oscilloscope whenever an ultrasonic interface is seen The specific operation of this unit will be the subject of a separate paper

Patient immobilization The inability to hold the patient s head in a fixed position was a great problem in obtaining ultrasonic pictures Several attempts at head immobilization led to less than satisfactory results, and an ultrasonic headholder was therefore designed and built This unit consists of a rigid angle iron frame holding both the headholder and scanner frame The headholder has adjustable posts which come in from either side and press on the patient s head just below the zygoma in front of the ear Another arm comes from beneath and presses on the patient s head just inferior to the external occipital protuberance A U shaped chinholder is then used, and this can be pressed up against the patient s chin (Fig 1) An auxiliary unit has been designed which will press gently on the roof of the mouth when an anesthetized

Fig 7 Coronal section at level of external auditory canal This picture was reduced to conform to the size of the ultrasound scan photograph shown in fig 8 The actual distance from the skin in the temporal area to the opposite side is identical in the two (From TRUEX and KELLNER Detailed atlas of the head and neck 1948 Courtesy of Oxford University Press Inc)

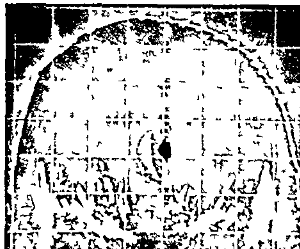
Fig 8 Coronal scan (with author as subject) at same level as shown in Fig 7 Superimposition shows pons perpontine space medial tips of temporal lobes upper portion of 4th ventricle posterior 3rd ventricle and petrous bone

patient is being scanned This rigid headholder has made it possible comfortably to immobilize the patient s head for as long as is desired for making ultrasonic pictures

Method The equipment in use here can cope with all possible horizontal coronal and oblique scans of the head The present work has concentrated on the use of the coronal scan

In this scan the scanning frame is horizontal and the transducer s position is just above the ear on one side The transducer holder is then oscillated approximately 5 in either direction and at the same time moved slowly around the side of the head and up to the vertex At this point a photograph is made of the half completed image on the storage tube oscilloscope The scan is then continued around to the other side of the head to complete the picture

The optimal number of degrees for compounding is currently under investigation It is believed that too wide a compounding angle could result in spurious echoes due to reflections and refractions within the skull bone The hair has caused no problem in our work. It is advisable to comb or push the hair out of the path of the scanning beam simply to aid in applying the contact material (Aquasonic Parker Laboratories Irvington New Jersey) The method of obtaining the scan and the developing scan on the storage tube oscilloscope are shown in Figs 2 to 6





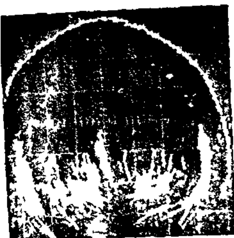


Figs 9 to 11 Ultrasound scan (top left) lateral arterial phase (lower right) and a p venous phase of angiography (top right) of first patient The arrow shows the displacement of the posterior 3rd ventricle on both the ultrasound scan and the a p angiogram (Case of proven metastasis to the left cerebral hemisphere from a carcinoma of the lung)

Results

The present work has concentrated on doing coronal scans The scanning plane we have most frequently used is from a point halfway between the nasion and the external occipital protuberance to a plane connecting the two external auditory canals Anatomically, this will pass through a plane of the head as shown in Fig 7

As shown in Fig 8 which is a representative example of the scans obtained, there is close correlation between the anatomical structure shown in the cross section and the structures shown on the ultrasonic coronal scan By actually superimposing Figs 7 and 8 we can show the following structures with some assurance 1) pons, 2) ambient cisterns, 3) medial tips of the temporal lobes, 4) possibly the upper portion of the aqueduct, 5) posterior third ventricle and the petrous bone







Figs 1? to 14 Ultras und scan (top left) lateral arterial phase (lower right) and a p venous phase (top r ght) of second pat ent. The arrow show ident cal d placement of th poster or 3rd ventricle (Case of proven gl obla toma of th left temporal lobe)

The midline structure extends slightly higher than we would expect by superimposing it on the anatomical picture This may in part be due to the anatomical picture being slightly anterior to the plane of the cut and the higher extent of the midline structure being the interhemispheric fissure and/or the *falx cerebri*

There are other structures noted in the region of the lateral ventricles These have not been shown with sufficient clarity in our studies to be positively identified In part they may represent portions of the lateral wall of the lateral ventricles choroid plexus and/or the internal capsule Also some lateral structures have been identified in the region of the sylvian fissure

The coronal scan from a patient with a primary carcinoma of the lung and clinical symptoms suggesting metastasis to the left cerebral hemisphere is shown in Fig 9 The midline echo presumably the posterior third ventricle is shown to be displaced 5 mm to the right of the midline The companion

structures laterally are fairly symmetrical and there is no evidence of distortion of the pons The lateral arteriogram, as well as the a p venous phase of the angiography, are reproduced in Figs 10 and 11 By superimposition, the position of the posterior third ventricle, as shown in the a p venous phase of the angiography, is identical with the structure shown in the echoencephalogram

In Fig 12 is shown the coronal scan of a patient whose clinical symptoms suggested a space occupying mass in the left cerebral hemisphere The scan shows a 1 cm displacement of the upper portion of the third ventricle to the right, and structures lateral to it, as well as the appearance of the pons, give the impression of midbrain rotation The lateral arterial phase and the a p venous phase are reproduced in Figs 13 and 14 and, again, the echo picture can be superimposed on the venous phase of the angiography

We are currently investigating the coronal sections behind or in front of the plane illustrated here as well as use of the transverse scans

Acknowledgement

Supported in part by Grant NB 04884 01 from the National Institute of Neurological Diseases and Blindness

SUMMARY

Cross sectional pictures of the head which are of definite clinical usefulness have been made By outlining the midbrain structures as well as the posterior third ventricular structures definite information can be gained as to the presence of a mass lesion

ZUSAMMENFASSUNG

Es wurden Transversalschnittbilder des Schädels deren klinischer Wert bewiesen war angefertigt Durch Darstellung der Mittelhirnstrukturen wie auch des hinteren Teiles des III Ventrikels kann man sichere Information über die Anwesenheit eines Tumors erhalten

RÉSUMÉ

Les auteurs ont obtenu au moyen des ultra sons des images de coupes de la tête qui présentent un réel intérêt clinique La mise en évidence des structures mésencéphaliques et de la partie postérieure du troisième ventricule renseigne sur la présence d une tumeur

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FROM THE INSTITUTE OF NEUROLOGY, LONDON, ENGLAND

TOPOGRAPHICAL CRITERIA FOR PATHOLOGICAL DIAGNOSIS OF INTRACRANIAL MASSES BY MEANS OF GAMMA ENCEPHALOGRAPHY

by

JAMES W D BULL

The purpose of this paper is to indicate to what extent the pathology of a given mass can be determined by photoscanning It is well known that the size, shape and position can be clearly defined Greater anatomical accuracy has recently been achieved by the method devised by MARRYAT & BULL (1964) It consists in taking an under exposed roentgenogram of the skull and leaving the image latent until after the scan When the film is processed, both the image of the scan and the skull outline are obtained This is illustrated in Figs 3, 4 and 5 It has been found that by reference to certain anatomical landmarks and their relation to the mass, the pathology can often be predicted Anatomical structures to which these masses have been related are (1) the dura, (2) the falx cerebri, (3) the tentorium cerebelli and (4) the corpus callosum Fig 1 shows the normal anatomy of the falx, tentorium and corpus callosum A fifth factor which has been taken into account is the presence of multiple masses *By studying these various features it has been possible* very often to predict the pathology of three common tumour types (1) meningiomas, (2) astrocytomas and (3) metastases

F g l Normal anatomy to how falx tentorium and corpus callosum (Courtesy E B Jamieson E & S L vingstone 17 Teviot Place Ed nburgh)

*Menin*g*iomas*

In 300 scan examinations 21 cases of meningioma were found in the follow ing sites

1 *Bifontal* One such example is illustrated in Fig 2 It is postulated that no other lesion could produce a similar appearance and transgress the midline in this manner

2 *Con exity* In this situation the diagnosis was not always quite so certain if one could not always be sure that the lesion actually came to the surface and involved the convexity dura However other features such as the heavy take up of the isotope uniform density and the sharp outline of the tumour all supported the diagnosis of meningioma (Fig 3)

3 *Falx* The criteri i of falx involvement are (1) transgression of the tumour *across* the midline in the anatomical situation of the falx (Fig 4) *or* (2), if the tumour is unilateral a straight medial edge to the tumour down the midline In these cases scanning in a third dimension — the vertical projection

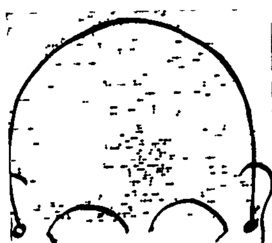




Fig 2

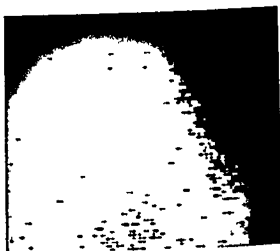


Fig 3

Fig 2 Bifrontal meningioma confirmed by surgical removal

Fig 3 Convexity meningioma confirmed by surgical removal

— can add further confirmation to the site of the mass Such a projection was used in the case illustrated (Fig 4, c and d)

It is likely that the vertical projection will play an increasing part in the future examinations, it has not yet been fully exploited

4 *Recurrences* The diagnosis was simple in three recurrent cases in that the previous site of the tumour and the pathology were both known One involved the tentorium (Fig 5)

Astrocytomas

Of the 31 astrocytomas, 6 were diagnosed on the scan as involving the corpus callosum unequivocally, and in three others it was strongly suspected

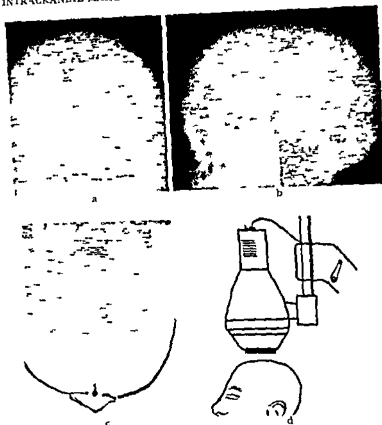


Fig 4 Falx meningioma confirmed by surgical removal

The diagnosis was made in most cases by biopsy occasionally by operation and three were confirmed at autopsy Fig 6 illustrates the scan of one of the cases confirmed at autopsy

Involvement of the corpus callosum is often very difficult to demonstrate by pneumography and angiography although it is sometimes possible It is submitted that the scanning method is the most reliable available and it serves two purposes (1) to demonstrate the site of the neoplasm and (2) to allow a very *confident pathological diagnosis to be made on the basis of the scan*

In 1957 Bull & Rovit studied 100 cases of supratentorial astrocytomas confirmed at autopsy with the object of assessing the accuracy of pneumography and angiography in delineating the extent of the tumours The corpus callosum was involved in one third of the cases


Fig 2

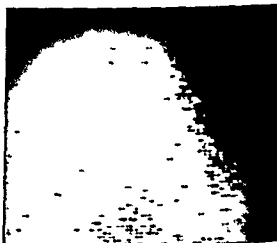

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Acknowledgement

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SUMMARY

By studying the topography of tumours demonstrated by photoscanning it is frequently possible to predict the pathology particularly in the case of meningiomas astrocytomas and metastases Meningiomas can often be diagnosed by noting their relation to the dura falx or tentorium Astrocytomas can be confidently diagnosed when the corpus callosum is seen to be involved When metastases are present multiple lesions were often shown thus enabling a diagnosis to be made

ZUSAMMENFASSUNG

Beim Studium der Topographie von Tumoren die mittels Photo-Scintillographie dargestellt werden, ist es oft moglich die Pathologie vorauszusagen besonders bei Fallen von Meningeomen Astrocytomen und Metastasen Meningeome konnen oft diagnostiziert werden wenn man ihre Beziehung zur Dura Falx oder Tentorium beachtet Astrocytome konnen mit Sicherheit festgestellt werden wenn das Corpus callosum befallen ist Bei Vorliegen von Metastasen zeigen sich oft multiple Veranderungen wodurch die Diagnose gestellt werden kann

RÉSUMÉ

L étude de la topographie des tumeurs montrées par la scintigraphie permet souvent de prévoir leur *nature anatomopathologique* en particulier dans le cas de méningiomes d astrocytomes et de métastases Leurs rapports avec la dure mère la faux ou la tente permettent souvent de diagnostiquer les méningiomes L atteinte du corps calleux permet le diagnostic d astrocytome Dans le cas de métastases la multiplicité fréquente des lésions permet le diagnostic

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Fig. 5. Tentorial meningioma (recurrence).

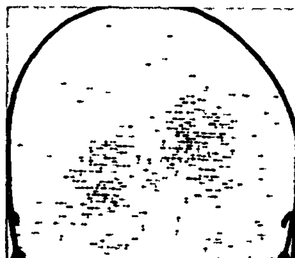


Fig. 6. Astrocytoma: splenium of corpus callosum and both parieto-occipital lobes. (Confirmed at autopsy.)

Metastases

There were 17 cases of metastases, 10 had single masses and the remaining 7 multiple. Without clinical or radiological aid, a correct pathological diagnosis clearly could not be made in the ten cases where a single mass was shown. However, in the remaining seven cases the pathology could be accurately predicted. Two metastases were shown in five, three in one and four in the seventh case.

It is thought that multiple metastases are more readily demonstrated by scanning than by either pneumography or angiography.

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SUMMARY

By studying the topography of tumours demonstrated by photoscanning it is frequently possible to predict the pathology particularly in the case of meningiomas astrocytomas and metastases Meningiomas can often be diagnosed by noting their relation to the dura falx or tentorium Astrocytomas can be confidently diagnosed when the corpus callosum is seen to be involved When metastases are present multiple lesions were often shown thus enabling a diagnosis to be made

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FROM THE ROENTGENDIAGNOSTIC DEPARTMENT (DIRECTOR PROF. OLLE OLSSON), AND THE DEPARTMENT OF NEUROLOGY (DIRECTOR PROF. RAGNAR MÜLLER), UNIVERSITY HOSPITAL, LUND, SWEDEN

QUANTITATIVE MEASUREMENTS OF REGIONAL CEREBRAL BLOOD FLOW RELATED TO NEURORADIOLOGICAL FINDINGS

by

STEN CRONQVIST, DAVID H. INGVAR and NIELS A. LASSEN

The majority of the disorders of the central nervous system are regional in character. It is a well known fact, however, that conventional neuroradiological procedures will give a definite diagnosis in only a part of such cases. It is therefore desirable to supplement our present techniques with others which yield information on regional disturbances within the brain.

One such method is the isotope clearance method, recently worked out by LASSEN et coll. (1963). This method permits measurements of the regional cerebral blood flow. In the following, a brief description of the method will be given, as well as some results obtained and their relation to the neuroradiological findings in a few typical cases. A detailed review is being prepared at present (INGVAR, CRONQVIST, EKBERG et coll.).

Two isotopes were used, ^{133}Xe and ^{85}Kr. Both are freely diffusible gamma emitting inert gases, which can be easily dissolved in small amounts of saline. For the clinical studies we have usually used about 0.5 mCi ^{133}Xe in 2 to 5 ml saline which was injected rapidly into the internal carotid artery. The uptake



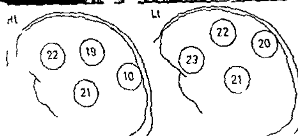


Fig 1 Male 77 years old Intracranial hemorrhage in right parietal region Bilateral decrease of blood flow values in all regions measured Area of minimal flow (10 ml/100 g/min) on the right side corresponds with expansivity as evident in angiogram

of the isotope and the subsequent clearance was recorded by means of four collimated detectors over different regions of the hemisphere

It can be shown that the clearance curve is a function of the blood flow in the regions covered by each detector This curve is an almost pure wash out curve since there is practically no recirculation due to the rapid elimination of the radioactive gas by the lungs Since the partition co efficient for the gases between the blood and the tissue is known it is possible to calculate the regional cerebral blood flow from the curves in terms of millilitres per 100 gram per minute (INGVAR & LASSEN 1962 HOEDT RASMUSSEN SVEINSDOTTIR & LASSEN 1966)

Analysis of the clearance curves has shown that they consist of two components which represent a slow and a fast type of flow There are reasons to believe that they are related to the blood flow within the grey and the white matter respectively (HOEDT RASMUSSEN SVEINSDOTTIR & LASSEN 1966)

Normal values for the method were obtained in seven young healthy male volunteers (INGVAR, CRONQVIST EKBERG RISBERG & HOEDT RASMUSSEN

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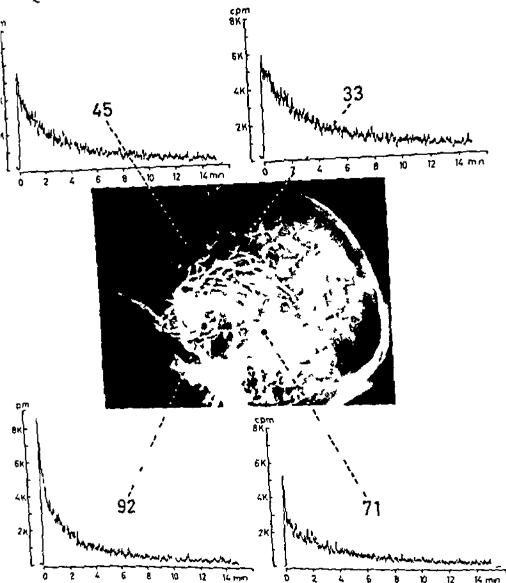
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F g 3 Wo n n 68 y ars old Mal gnant gl oma w th abundant arterio nous shunts in left temporal region Flow values with n and close to the tumour reg on a e h ghly increased In surround ng ar a alues a e significantly lower than normal In t l peak in clearance curves from tumour a ea cha act rist c of arte io v nous shunts



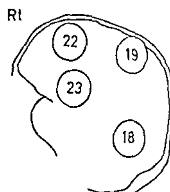


Fig 2 Male 60 years old Occlusion of right middle cerebral artery The regional blood flow within occluded area is lower than in the rest of the hemisphere

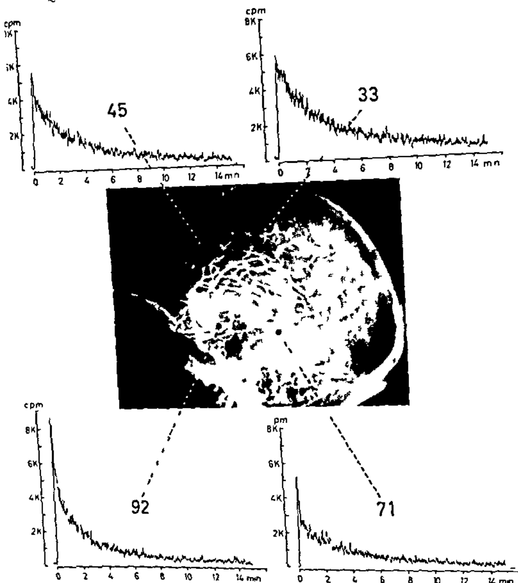
1965) The average regional cerebral blood flow value measured in four standard regions was found to be 54 5 ml/100 g/min (± S D 5 1), a figure corresponding well with values obtained with the nitrous oxide technique of KETY & SCHMIDT (1948) The relation between the fast type of flow and the slow type was about 4 to 1

The cases to be related here illustrate the value of regional measurements of the cerebral blood flow in different brain disorders

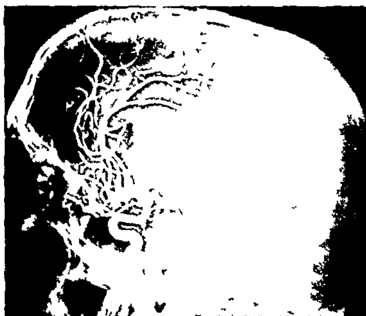
The first case pertains to the *cerebro vascular group* (Fig 1) This patient had suffered from a left sided hemiplegia with slow onset A carotid angiography showed a large expansive lesion in the left parietal region In the corresponding area the regional blood flow was found to be only about one fifth of the normal Two days later the patient died and the autopsy confirmed the presence of a massive intracerebral hemorrhage in the region where the changes of the angiogram were seen and where the minimal cerebral blood flow was measured

In this case, as well as in similar ones, it was also noted that the flow in other regions surrounding the lesion and on the contralateral side, was very much reduced Similar findings with the same method have been reported by HOEDT RASMUSSEN & SKINHOJ (1964)

Fig 2 shows a case with an occlusion of the right middle cerebral artery The regional blood flow within the occluded area is lower than in the rest of the hemisphere All flow values show a significant decrease, however as in the first case presented



F g 3 Woman 68 years old Mal gnant gl oma with abundant a ter ovenous shunts in left temporal g on Flow val es with n and close to the tumour reg on are h ghly increased In surround ng r a values are gn ficantly lower than n rmal Initial peak in cl a ance curves from tumour area ha a ter t c of arter o-venous shunts



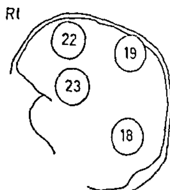


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pared to that at low pressure It was furthermore noted that the diameter of the cerebral arteries was larger at the high pressure, indicating that a general vasodilatation at least of the largest cerebral vessels had taken place A group of similar cases are at present being studied systematically and the results will be published later (CRONQVIST INGVAR & LUNDBERG)

Conclusions

The present new method permits a simultaneous quantitative measurement of the blood flow in different regions of the brain

In cases with regional abnormalities as shown by neuroradiological examinations it has been possible to confirm and to quantitate these abnormalities in terms of regional blood flow per 100 gram tissue and minute

In several cases with normal radiological findings the measurements of the cerebral blood flow have nevertheless revealed abnormal conditions in most cases a decrease of the flow

A combined study of the cerebral circulation both from a morphological standpoint in neuroradiological procedures and physiologically by means of the isotope technique presented has enabled a study of new aspects of cerebral hemodynamic conditions

Acknowledgements

The present investigation was supported by grants from the Swedish Medical Research Council the Wallenberg Foundation and the Fylgia Insurance Company

SUMMARY

The uptake and clearance within the brain tissue of ^{133}Xe dissolved in saline and injected into the internal carotid artery have been recorded Multiple regions have been measured simultaneously through the intact skull Blood flow was calculated in terms of ml per gram per minute The results in normal subjects and in patients with different lesions of the brain are briefly reported

ZUSAMMENFASSUNG

Aufnahme und Clearance von ^{133}Xe das in einer Salzlosung in die Art carotis int injiziert wurden war wurde registriert Es wurden viele Stellen gleichzeitig durch den intakten Schadel hindurch gemessen Die Blutzirkulation wurde in Milliliter per Gramm per Minute errechnet Es wird über die Resultate bei Normalen und Patienten mit verschiedenen Hirnschaden berichtet

These two cases with regional cerebral circulatory disturbances showed a fair correlation between the angiographic findings and the regional blood flow measurements Within the cerebrovascular group so far investigated there are, however, other cases, usually with less severe symptoms or with symptoms of the transient type, which do not show any abnormality angiographically and which have a normal circulation time angiographically determined Such cases usually have shown an overall decrease of the cerebral blood flow, determined with isotope methods, but so far we have not been able to detect significant regional circulatory difference with the present collimator equipment We are exploring the possibility of increasing the resolution of the method by other forms of collimators

Cases with *general cerebral atrophy* have in most instances shown an overall reduction of the flow with no apparent regional differences One such case was a woman of 74 with severe dementia and cerebral atrophy A carotid angiography was normal The regional cerebral blood flow in three regions measured (the premotor, the central and the parietal region) was found to be about equally reduced (36, 31 and 33 ml per 100 gram per minute, respectively) In another similar case, a woman of 74, also with severe dementia and cerebral atrophy, an overall reduction of the flow was found in four areas measured to be about 30 % below the normal without any apparent regional differences

Fig 3 shows a case from the *brain tumour* series with a malignant glioma in the left temporal region with abundant arterio venous shunts The figure demonstrates the clearance curves obtained from different parts of the hemisphere on the tumour side It is seen that the flow values within, and close to, the tumour region are highly increased, in comparison to those in the regions surrounding the tumour, which were significantly lower than normal The high values are explained by the shunts which give a marked initial peak in the clearance curves, due to the very rapid elimination of part of the isotope by the pathological vessels (HAGGENDAL et coll 1965)

In this patient another most interesting finding was made She suffered from increased intracranial pressure with so called plateau waves (LUNDBERG 1960), that is, recurrent spontaneous periods of markedly elevated intraventricular pressure Measurements of the blood flow were made when the pressure was low, and when it was high during a plateau wave A significant difference was found with a flow value of 40 ml/100 g/min at an average pressure of 25 mm Hg and 28 ml/100 g/min at the high pressure (about 80 mm Hg)

The corresponding angiograms showed that during the high pressure, when the flow was decreased, the circulation time was markedly *elongated as com*

FROM THE WALTER REED ARMY INSTITUTE OF RESEARCH DEPARTMENT OF NEURO PHYSIOLOGY AND NEUROSURGERY SERVICE WALTER REED GENERAL HOSPITAL WALTER REED ARMY MEDICAL CENTER WASHINGTON D C, U S A

EVALUATING INTRACRANIAL HEMATOMA BY ECHO EG

by

M J DREESE G J HAYES and L G KEMPE

Unlike intracranial neoplasm that often determines prognosis by position and inherent degree of malignancy intracranial hematoma may be less a determinant than our *response to it* The rapid diagnosis of acute epidural hematoma frequently *results in* early craniotomy and recovery from a potentially fatal lesion Acute and chronic subdural hematoma although usually not of such immediate *threat* if unrecognized can also cause death (9)

Need for craniotomy is usually based on clinical and arteriographic findings The history and physical examination frequently allow ischemic and hemorrhagic disease to be distinguished but evaluation of a comatose patient for whom an adequate history *is unobtainable* may be most difficult There are occasions too when arteriography is not used for a definitive diagnosis If extra cerebral hematoma is suspected *in elderly* patients trephination may be preferred to angiography because of the higher incidence of arteriographic complications in this age group Arteriography is widely used but trephination is still available in localities lacking *facilities* for contrast studies Early trephination may be life saving on occasion and cannot be delayed There are occasions

RÉSUMÉ

Les auteurs ont enregistré la fixation et la clearance dans le tissu cérébral du ^{133}Xe dissous dans une solution salée physiologique injectée dans l'artère carotide interne. Ils ont mesuré simultanément à travers le crâne intact l'activité de plusieurs régions cérébrales. Ils ont calculé le débit sanguin en ml par gramme par minute. Ils rapportent brièvement les résultats obtenus chez des sujets normaux et chez des malades atteints de diverses lésions cérébrales.

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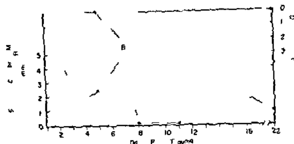


Fig 1 Correlation of cerebral midline shift and state of consciousness Carotid arteriography showed cerebral edema (A) Repeat arteriography demonstrated a subdural hematoma (B) Lessening of both confusion (upper graph) and midline shift (lower graph) followed removal of the hematoma

seen two days after sustaining cranial trauma The echogram showed a cerebral midline shift of 5 mm later confirmed by angiography although no hematoma was seen His recovery from cerebral concussion was evidenced both by lessening of confusion and midline shift After initial improvement, he again became disoriented and was found to have a progressive recurrence of a 5 mm midline shift Repeat angiography revealed a subdural hematoma After craniotomy midline shift disappeared and the patient became and remained mentally alert Although it was not possible on the basis of a single reading of midline shift correctly to differentiate edema from hematoma discovery of recurrence of shift several days after initial improvement was most suggestive of hematoma formation As with EEG the information gained from serial studies may be of greater value than from multiple readings considered individually

Although serial Echo EG findings are useful in evaluating cranial trauma it would be of great value to have a means of detecting intracranial hematoma at the time of initial examination

Acute cranial trauma if severe usually results in both hemorrhage and cerebral swelling Nevertheless even when swelling is prominent removal of a complicating hematoma might be life saving (1), especially were uncal herniation impending Decompression by removal of calvarium is not without risks in the presence of cerebral edema severe enough to shift the midline Drugs used to decrease cerebral swelling should not be used if intracranial bleeding is suspected Despite the possibility of complications angiography has been needed to verify the presence of acute intracranial hemorrhage (4 1 10 2 7 8) Reliable Echo EG detection of acute hematoma would thus be most valuable when serial examinations are not possible For this difference in the Echo EG pattern between intracranial hemorrhage and swelling must be found

Our experience to date suggests that although no single difference is diagnostic several echographic variations when combined may be quite helpful

when arteriography, although available and indicated, cannot be performed. Permission may be refused and rarely, sensitivity to contrast media may exist.

Clearly, despite its high diagnostic reliability, arteriography may be a less than satisfactory means of diagnosing extracerebral hemorrhage in a specific case. It may be refused, unavailable, relatively contraindicated, or rejected because of clinical need of immediate craniotomy.

On these occasions, Echo EG, a useful adjunct to arteriography (5), *becomes* especially valuable. Although less information is gained from Echo EG than from arteriography, it is available more quickly and often gives adequate data to indicate the need for trephination. Under such circumstances, the ready availability of Echo EG compensates for less detailed data.

However, Echo EG is not the definitive study of choice in cases of suspected extracerebral hemorrhage because of the occurrence of false positive and negative findings. Until Echo EG refinements can prevent false negative studies from bilateral hematoma and false positive studies from cerebral edema, it cannot approach the diagnostic reliability of arteriography. A single midline determination may be of aid to clinical judgement, but although it may indicate a need for definitive arteriography, it cannot itself establish or disprove the presence of hematoma with certainty. In practice the delay and added risk of certain diagnosis is often balanced against the benefits of direct trephination. Improved Echo EG reliability would aid in making this decision.

There appear to be at least two means of increasing the value of Echo EG in these cases. Accumulating knowledge of the predicted pattern of midline shift from various lesions may be applied, to interpret serial Echo EG reading more correctly, and the technique of Echo EG can be modified by use of lateral *echoes, to increase the yield of data. Examples are given from three years'* experience where both methods proved of clinical value. The illustrative cases are chosen from over 150 patients seen because of suspected intracranial hematoma.

Consideration of the time interval between cranial trauma and the initial Echogram may suggest the cause of the shift. For example, presence of cerebral midline shift days after cranial trauma is suggestive of hemorrhage. It is not known however, just how many days shift may remain from posttraumatic swelling alone. Incomplete evidence suggests lessening of traumatic cerebral edema in three to five days but more data are needed before patterns of shift occurrence and resolution are well established (11). Nevertheless, whereas interpretation of a single reading is difficult, serial Echo EG readings are often clinically useful. Midline shifts secondary to acute trauma may result from either swelling or cerebral hemorrhage. Serial readings may suggest which is responsible, as shown in the following case (Fig. 1). A 20 year old soldier was

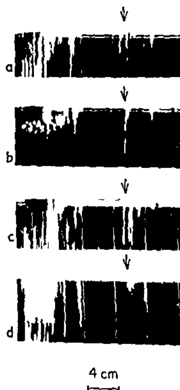


Fig 4 Comparison of echo EG recordings before and after removal of extracerebral hematoma in two cases a) Subdural hematoma the ultrasound passed through the brain and reflected from the opposite skull table seen to the right of the arrow An echo is also seen to the left of the arrow prior to removal of the clot b) Post operative echogram The unusual echo is no longer present c) and d) Epidural hematoma the echo to the left of the arrow seen preoperatively c) is absent after removal of the epidural hematoma (d)

ment toward the inner table of the skull would be expected This is in fact seen (Fig 2 a) These data suggest that the extent of insular as well as midline shift may be useful in evaluating cranial trauma To compare bilateral structures measurements must be made from points consistently related to fixed external symmetrical anatomic structures such as the external auditory meati Subsequent measurements should be made from the points originally chosen Insular determinations are usually taken about 4 cm above and 2 cm anterior to the external auditory meatus

The usefulness of the insular echoes was not fully realized when the echograms shown by the first figure were taken In retrospect the echogram taken when the midline shift resulted from swelling was compared to the echograms with shift from hematoma Fig 3 thus compares two echograms from the same 20-year-old patient Normal insular position was seen (Fig 3a) when arteriography showed only diffuse hemispheral swelling whereas medial insular shift is seen (Fig 3 b) when an extracerebral hematoma had developed

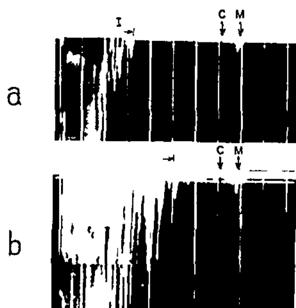


Fig 2 *Comparison of lateral echoes from 2 patients* with equal extent of midline shift a) Cerebral edema solid arrows indicate positions of both cranial and cerebral midline Echo from cerebral midline (M) is displaced to right of midline control position (C) Insular echoes (I) extend only 3 cm deep to probe position on far left b) Subdural hematoma the extent of cerebral midline shift equals that seen in a) whereas lateral echoes extend 5 cm toward the shifted midline suggesting shift of both insula and cerebral midline structures

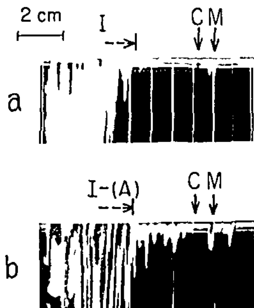


Fig 3 *Comparison of echograms of* the same patient studied on two occasions a) Cerebral edema the cerebral midline structures (M) are displaced to the right of the cranial midline (C) b) Subdural hematoma the cerebral midline echo is displaced equally as in a) but prominent echoes appear further from the probe because the insula as well as midline structures are now shifted by subdural hematoma The broken arrow indicates the initial depth of insular echoes

The first example is shown by cases 2 and 3 (Fig 2) Fig 2, a and b are enlarged echograms of two patients evaluated for cranial trauma The cranial midline control distance of both patients was fortuitously equal, and the cerebral midlines were shifted 9 mm Both echograms showed identical cranial midlines and equal extend of cerebral shift

The lesions responsible for the shift were found to be quite different however The first patient (Fig 2 a) died, and was found at necropsy to have a diffusely swollen brain without extracerebral hemorrhage The second patient (Fig 2 b) recovered after evacuation of a subdural hematoma The two echograms differ in the extent of lateral echoes These echoes located several centimeters deep to the inner table arise from the operculum of the temporal lobe and extend to the insula (6) Extra cerebral hematoma superficial to the insula causes considerable insular, as well as midline shift (Fig 2 b) Diffuse hemispheral swelling would not be expected to cause significant insular displacement Indeed, if swelling medial to the insula were relatively more severe, displace-

ung war bei der Differenzialdiagnose zwischen Ödem und Hamatom wertvoll Echos die direkt von epiduralen — und subduralen Hamatomen ausgehen werden mit chirurgischen und radiologischen Kontrolluntersuchungen verglichen

RÉSUMÉ

Il faut utiliser pour le diagnostic tous les renseignements que peut donner l écho encéphalographie Cette technique se compare plutot à la radioscopie qu à la radiographie L enregistrement en serie du déplacement de la ligne médiane et celle des échos latéraux donne des renseignements que ne fournit pas le seul enregistrement de la ligne médiane La comparaison du déplacement insulaire et du déplacement de la ligne médiane est utile pour distinguer l œdème de l hématome Les échos provenant directement d hématomes extra-duraux et sous-duraux ont été comparés aux examens radiologiques et per opératoires

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The time sequence of shift recurrence was most helpful in this case, although in retrospect even more data were present but unrecognized

Another aid in detecting extracerebral hemorrhage is to note presence or absence of extra echoes inside the far skull table when recording from the side opposite a suspected hematoma This technique is not original, and we found, as have others (3), both false positive and negative readings Two illustrative cases follow however, where echoes did originate from hematoma The echograms of two patients before and after surgery were compared (Fig 4) The inner table echo is to the right of the arrow, but in both cases an unusual echo appeared inside to the left of the arrow before surgery The lesion responsible for midline shift (Fig 4 a) and occupying the region of the unusual echo source was found to be a subdural hematoma enclosed by membranes A repeat echogram after craniotomy showed the echo inside the inner table to be absent (Fig 4 b) There was no midline displacement The second patient (Fig 4 c) was shown by angiography to have an epidural hematoma An echogram following craniotomy showed disappearance of the unusual echo (Fig 4 d) previously seen to arise from the position of the dural hematoma interface

Because both false positive and negative findings occur, little reliability can presently be given to hematoma echoes alone When evaluated together with the extent of midline shift, position of insular echoes and neurological history and findings, they become much more meaningful

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SUMMARY

All possible clues obtainable by Echo EG must be used if the diagnostic potential is to be achieved The study is best likened to fluoroscopy not radiography Serial recordings of midline shift and use of lateral echoes gave valuable information not available from a single midline recording Comparison of insular to midline shift was useful in distinguishing edema from hematoma Echoes arising directly from epidural and subdural hematomas are compared to surgical and radiographic controls

ZUSAMMENFASSUNG

Alle moglichen Spuren die man mittels Echo EG erhalten kann mussen fur die Diagnose ausgenutzt werden Die Untersuchung ahnelt eher der Durchleuchtung als der Radiographie Wiederholte Untersuchungen geben Informationen die man mit einer einzigen Mittellinien Untersuchung nicht erhalten kann Vergleich der Insel — und Mittellinien — Verschieb

Im *Angiogramm* ergibt sich die Lokalisation des Tumors aus der Gefäßverlagerung und die Artdiagnose aus der ‚Tumoranfarbung' in einer bestimmten für die Tumorart typischen Phase der Zirkulation des Kontrastmittels sowie aus charakteristischen arterio venosen Kurzschlußverbindungen und der dadurch erfolgenden vorzeitigen Venenfullung Bei der *Positronenszintigraphie* (PCG) sind aus dem Ort und dem Grad der Anreicherung lokalisatorische und artdiagnostische Schlusse zu ziehen, wobei sich auch aus einer Zone verminderter Aktivitatsaufnahme (WILCKE 1961) in Verbindung mit dem angiographischen Befund Hinweise fur die Artdiagnose ergeben konnen

Meningiome (71) sind von allen raumfordernden intracraniellen Prozessen im PCG durch ihre besonders starke und zumeist umschriebene Anreicherung der Aktivitat am sichersten zu erfassen In 96 % der Falle war eine entsprechende Lokalisation und in 72 % der Falle zudem die Artdiagnose mit großer Wahrscheinlichkeit zu stellen Das Angiogramm erbrachte bei 69 der 71 Patienten den Nachweis eines raumfordernden Prozesses und erlaubte auf Grund der typischen homogenen Anfarbung in der venosen Phase in 70 % der Falle die Artdiagnose festzulegen Bei dem Vergleich der Untersuchungsbefunde zeigte es sich daß die Anwendung der PCG besonders dann indiziert ist wenn infolge der atypischen oder fehlenden Anfarbung die Entscheidung Meningiom Gliom offen bleiben muß Dies trifft besonders fur die parietal und occipital neben der Medianen liegenden Meningiome zu die im Gefäßbild haufiger nur eine Abdrangung und Verlagerung einzelner Gefaßabschnitte bedingen im Szintigramm hingegen zu einer kraftigen Anreicherung fuhren und dadurch ihrer Art nach bestimmt werden konnen Andererseits sind die mittelstandigen para oder suprasellar gelegenen Meningiome im Szintigramm ganz allgemein und besonders hinsichtlich ihrer Artdiagnose schlechter nachzuweisen als im Angiogramm da die Aktivitat in Temporalmuskel die Tumoranreicherung uberdeckt Durch die Kombination von Angiographie und Szintigraphie war in 93 % der Falle eine Artdiagnose moglich Bei den verbleibenden 7 % handelte es sich fast ausschließlich um die Gruppe der suprasellaren Meningiome

Astrocytome (43) sind im PCG von allen Tumoren am schlechtesten nachzuweisen manche Typen nehmen keinerlei Aktivitat auf so daß dann sogar die Aktivitat der gesunden Seite uberwiegt So war nur in knapp 60 % der Falle mit dem PCG mit der Angiographie jedoch bei 88 % die Tumorlokalisation moglich Beide Methoden zusammen erbrachten bei 91 % eine zutreffende Lagebestimmung Fur die artdiagnostische Zuordnung laßt sich außer der Anamnese und Klinik die durchweg geringe Anreicherung der

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GEGENÜBERSTELLUNG DER SERIENANGIOGRAPHISCHEN UND SZINTIGRAPHISCHEN ERGEBNISSE BEI 242 HIRNTUMOREN

von

G FRIEDMANN und O WILCKE

Der klinische Wert der Carotis Serienangiographie zum Nachweis und zur Artbestimmung von Hirntumoren ist unbestritten Um jedoch die Bedeutung der erst seit wenigen Jahren gebrauchlichen Isotopen Methoden endgultig zu klaren, bedarf es hinsichtlich der artdiagnostischen Moglichkeiten noch weiterer Erfahrung und vergleichender Untersuchungen Aus diesem Grund soll uber die angiographischen und szintigraphischen Befunde und die dabei gewonnenen Erkenntnisse bei 242 auch operativ bzw histologisch gesicherten Hirntumoren berichtet werden

Die Serienangiographie erfolgte nach der Methode von TONNIS & SCHIEFER (1959), die Szintigraphie wurde mit den Positronenstrahlern Arsen (^{74}As) und Kupfer (^{64}Cu) nach den Angaben von BROWNELL & SWEET (1956) vorgenommen

Im Einzelnen handelte es sich um 71 Meningiome, 43 Astrozytome, 37 Glioblastome, 28 Oligodendrogliome, 27 Metastasen, 16 Hypophysentumoren, 8 Epidermoide, 6 Ependymome und 6 Sarkome

Im *Angiogramm* ergibt sich die Lokalisation des Tumors aus der Gefäßverlagerung und die Artdiagnose aus der ‚Tumoranfärbung' in einer bestimmten für die Tumorart typischen Phase der Zirkulation des Kontrastmittels sowie aus charakteristischen arterio-venösen Kurzschlußverbindungen und der dadurch erfolgenden vorzeitigen Venenfüllung. Bei der *Positronenszintigraphie* (PCG) sind aus dem Ort und dem Grad der Anreicherung lokalisatorische und artdiagnostische Schlüsse zu ziehen, wobei sich auch aus einer Zone verminderter Aktivitätsaufnahme (WILCKE 1961) in Verbindung mit dem angiographischen Befund Hinweise für die Artdiagnose ergeben können.

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Aktivität in der gesamten Hemisphäre und insbesondere im Tumorgebiet in Verbindung mit der fehlenden Anfärbung im Angiogramm verwerten.

Glioblastome (37) führen im PCG in der Mehrzahl zu einer in ihrer Intensität den Meningiomen ähnlichen Anreicherung. Eine Unterscheidung ergibt sich vielfach aber durch die im Vergleich zu den Meningiomen mehr diffuse und weniger gut gegen die Umgebung abgesetzte Anreicherungszone. 82,5 % der Glioblastome konnten szintigraphisch, 97 % anhand des Angiogramms lokalisiert werden. Da es sich bei dieser Gruppe von Patienten zumeist um atypisch verlaufende Glioblastome handelte, fanden sich nur bei gut der Hälfte der Fälle typische angiographische Kriterien. Im Szintigramm konnte bei 16 Patienten aus der Art der erwähnten Anreicherung auf das Vorliegen eines Glioblastoms geschlossen werden. Die Kombination beider Methoden ergab bei 68 % eine richtige Artdiagnose.

Oligodendrogliome (28) zeigen ebenfalls eine nur geringe Aktivitätsaufnahme, die unseren Erfahrungen nach aber doch durchweg etwas ausgeprägter ist als bei den Astrozytomen. Wenn daher auch aus dem PCG allein keine Artdiagnose zu stellen ist, so eignet sich die Methode doch sehr gut zum Ausschluß eines Meningioms oder Glioblastoms. Insgesamt wurden von den 28 Oligodendrogliomen 21 (75 %) im PCG und 25 (89 %) im Angiogramm erfaßt. Durch die Kombination beider Methoden erhöhte sich der Prozentsatz sogar auf 96 % = 27 Patienten.

Metastasen (27) reichern die Aktivität in sehr unterschiedlichem Maße an, in der Regel nehmen Metastasen eines Mamma-Carcinoms mehr Aktivität auf als die cerebralen Absiedlungen der Bronchial-Carcinome und Melanome, so daß bei ersteren am häufigsten der szintigraphische Nachweis gelingt. Insgesamt war bei 4/5 aller Fälle im PCG ein pathologischer Befund vorhanden. Verschiedentlich konnte die Diagnose auf Grund mehrerer Anreicherungszonen im Szintigramm exakt gestellt werden. Im Angiogramm kam es bei 24 Fällen (89 %) zur Darstellung eines krankhaften Befundes. Durch die Kombination von Angiographie und PCG gelang es ohne Ausnahme einen raumfordernden Prozess nachzuweisen.

Hypophysentumoren (16) nehmen in diesem Rahmen insofern eine Sonderstellung ein, als zu ihrem Nachweis meist eine Nativaufnahme des Schädels und insbesondere des Sellagebietes genügt, so daß die Angiographie nur bei besonderen Fragestellungen zur Klärung der supra- oder parasellaren Ausdehnung des Tumors benötigt wird. Aus diesem Grund ist ein nur unvoll

standiger Vergleich mit den szintigraphischen Untersuchungen moglich bei denen es 12 mal zu einer starkeren Anreicherung der Aktivitat kam Diese gute Nachweisbarkeit im PCG ist offenbar dadurch bedingt daß die Anreicherung im Adenom nicht wie z B bei den gliomatosen Tumoren uber eine Storung der Blut Hirnschranken Funktion erfolgt sondern diese Tumoren ahnlich den parenchymatosen Organen anderer Korperregionen mehr Radioaktivitat aufnohmen als normales Hirngewebe

Epidermoide (8) reichern keine Aktivitat an Die Lokalisation und sogar die Artdiagnose gelingen jedoch recht haufig wenn das Angiogramm nur eine Gefaßverlagerung, aber keine Anfärbung zeigt im Szintigramm aber auf der gesunden kontralateralen Seite mehr Aktivitat aufgenommen wurde als in der Tumorregion Dies war bei unseren Beobachtungen mit einer Ausnahme der Fall hier bestanden bereits erhebliche allgemeine Hirndruckzeichen

Ependymome (6) werden auf Grund ihrer Lokalisation in der Regel durch die Hirnkammerluftfullung diagnostiziert Von den 6 angiographisch untersuchten Fallen zeigten 5 einen pathologischen Befund im Sinne einer Gefäßverlagerung oder geringen Anfarbung Im Szintigramm war 4 mal eine deutliche Anreicherung der Aktivitat zu beobachten Kriterien, die zur Artdiagnose herangezogen werden konnten fanden sich allerdings nicht

Sarkome (6) bewirken besonders wenn es sich um ein sarkomatos entartetes Meningiom handelt eine ahnlich starke Anreicherung wie die Meningiome und sind daher artdiagnostisch allein im PCG nicht von ihnen zu differenzieren 5 der 6 Sarkome wiesen im Szintigramm eine erhebliche Aktivitatsaufnahme auf, wahrend einmal keine Anreicherung zustande kam Angiographisch war bei allen Fallen die Tumorlokalisation infolge einer Gefäßverlagerung moglich 4 mal kam es außerdem zu einer Anfarbung die in einem Fall die Charakteristika eines Meningioms aufwies

ZUSAMMENFASSUNG

Sinn der Ausfuhrungen war die Moglichkeiten und Grenzen der angiographischen und szintigraphischen Diagnostik der *Großhirnhemisphärentumoren* aufzuzeigen Die Angiographie ist sowohl hinsichtlich der *Tumorlokalisation* als auch der Artdiagnose fur den Nachweis gliomatoser Tumoren zuverlassiger als die Szintigraphie wahrend bei den Meningiomen beide Verfahren nahezu *Gleichwertiges* leisten Die Kombination der Methoden fuhrt mit Sicherheit zu einer eindeutigen Verbesserung der Resultate

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Glioblastome (37) führen im PCG in der Mehrzahl zu einer in ihrer Intensität den Meningiomen ähnlichen Anreicherung. Eine Unterscheidung ergibt sich vielfach aber durch die im Vergleich zu den Meningiomen mehr diffuse und weniger gut gegen die Umgebung abgesetzte Anreicherungszone. 82,5 % der Glioblastome konnten szintigraphisch, 97 % anhand des Angiogramms lokalisiert werden. Da es sich bei dieser Gruppe von Patienten zumeist um atypisch verlaufende Glioblastome handelte, fanden sich nur bei gut der Hälfte der Fälle typische angiographische Kriterien. Im Szintigramm konnte bei 16 Patienten aus der Art der erwähnten Anreicherung auf das Vorliegen eines Glioblastoms geschlossen werden. Die Kombination beider Methoden ergab bei 68 % eine richtige Artdiagnose.

Oligodendrogliome (28) zeigen ebenfalls eine nur geringe Aktivitätsaufnahme, die unseren Erfahrungen nach aber doch durchweg etwas ausgeprägter ist als bei den Astrozytomen. Wenn daher auch aus dem PCG allein keine Artdiagnose zu stellen ist, so eignet sich die Methode doch sehr gut zum Ausschluß eines Meningioms oder Glioblastoms. Insgesamt wurden von den 28 Oligodendrogliomen 21 (75 %) im PCG und 25 (89 %) im Angiogramm erfaßt. Durch die Kombination beider Methoden erhöhte sich der Prozentsatz sogar auf 96 % = 27 Patienten.

Metastasen (27) reichern die Aktivität in sehr unterschiedlichem Maße an, in der Regel nehmen Metastasen eines Mamma-Carcinoms mehr Aktivität auf als die cerebralen Absiedlungen der Bronchial-Carcinome und Melanome, so daß bei ersteren am häufigsten der szintigraphische Nachweis gelingt. Insgesamt war bei 4/5 aller Fälle im PCG ein pathologischer Befund vorhanden. Verschiedentlich konnte die Diagnose auf Grund mehrerer Anreicherungszonen im Szintigramm exakt gestellt werden. Im Angiogramm kam es bei 24 Fällen (89 %) zur Darstellung eines krankhaften Befundes. Durch die Kombination von Angiographie und PCG gelang es ohne Ausnahme einen raumfordernden Prozess nachzuweisen.

Hypophysentumoren (16) nehmen in diesem Rahmen insofern eine Sonderstellung ein, als zu ihrem Nachweis meist eine Nativaufnahme des Schädels und insbesondere des Sellagebietes genügt, so daß die Angiographie nur bei besonderen Fragestellungen zur Klärung der supra- oder parasellären Ausdehnung des Tumors benötigt wird. Aus diesem Grund ist ein nur unvoll

AUS DER NEUROCHIRURGISCHEN UNIVERSITÄTSKLINIK (DIREKTOR PROF H W PIA) GIESSEN DEUTSCHLAND

ECHOENCEPHALOGRAPHIE BEI CEREBRALEN ERKRANKUNGEN IM SÄUGLINGS UND KINDESALTER

von

CARL LUDWIG GELETNEKY

Die Echoencephalographie im Kindesalter beruht grundsätzlich auf den gleichen bisher erarbeiteten physikalischen Grundlagen wie im Erwachsenenalter Besondere Erwähnung über das normale Echoencephalogramm und die Mittellinienstrukturen bei Kindern finden sich in den Arbeiten von JEPPSSON und LITHANDER In der zusammenfassenden Arbeit von SCHIEFER KAZNER & BRÜCKNER wird besonders auf den kindlichen Hydrocephalus eingegangen

Wir untersuchten echoencephalogisch 125 Kinder mit cerebralen Erkrankungen Besonders günstige Voraussetzungen für die Anwendung der Echoencephalographie in diesem Alter waren

1 Atrophische und zystische Veränderungen als Folge der spezifischen Reaktionsweise des unreifen Gehirns die Häufigkeit subduraler Hämatome und Hydrome verschiedenartiger Hydrocephalusformen und damit die Existenz von Medien und Grenzflächen verschiedener Schallgeschwindigkeit

2 Die anatomischen Verhältnisse des kindlichen Schädels mit dünnem Lamellenknochen (0 5—4 *mm*) und tiefstehende Schädelbasis somit hohe Echoamplituden infolge geringer Schallabsorbation und Fortfall von störenden Effekten durch basale Strukturen

SUMMARY

An attempt is made to demonstrate the possibilities and the limits of the angiographic and scintigraphic diagnosis of tumours of the cerebral hemispheres. Angiography appears more successful in demonstrating the site and character of the lesion in the case of gliomas but both methods seem to have equal merits in angiomas. The combination of the two methods leads undoubtedly to more reliable results.

RÉSUMÉ

Le but de ce travail était de déterminer les possibilités et les limites du diagnostic angiographique et scintigraphique des tumeurs des hémisphères cérébraux. L'angiographie est plus fidèle que la scintigraphie pour la localisation et le diagnostic de nature des tumeurs gliomateuses alors que pour les méningiomes les résultats des deux méthodes sont à peu près équivalents. L'association des deux méthodes apporte incontestablement une notable amélioration des résultats.

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Abb. 3. Zystisches Plexuspapillom im Bereich des linken Parietallappens

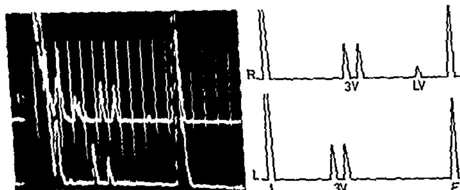


Abb. 4. Linksseitige Hirnatrophie

Hydrocephalus. Die Diagnose des Hydrocephalus aller Formen ist durch die Weite des 3. Ventrikels, der Seitenventrikel und die Messung der Hirnmanteldicke möglich. Kennzeichnend bei der Untersuchung sind sehr hohe Echoamplituden. Schädelasymmetrien können die Beurteilung erschweren. Da die Größe des *Hydrocephalus* exakt bestimmt werden kann, stellen Verlaufsbeobachtungen während der *Entstehung* eines Hydrocephalus bzw. seiner Rück-

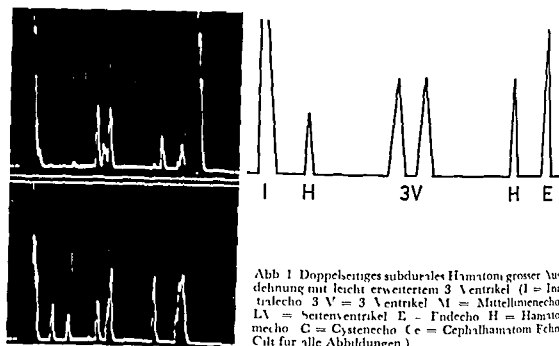


Abb. 1. Doppelseitiges subdurales Hämatom grosser Ausdehnung mit leicht erweitertem 3. Ventrikel. (I = Initialecho, 3 V = 3. Ventrikel, M = Mittellinienecho, LV = Seitenventrikel, E = Endecho, H = Hämatomecho, C = Cystenecho, Ce = Cephalhämatom-Echo. Gilt für alle Abbildungen.)

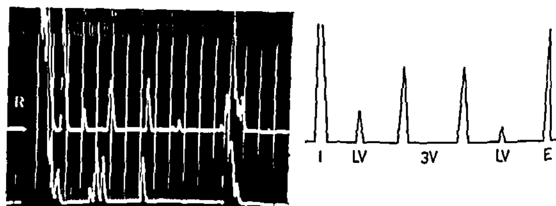


Abb. 2. Hydrocephalus occlusus

Diese idealen Vorbedingungen erlauben eine breite Indikation der Echoencephalographie im Kindesalter.

Subdurale Hämatome und Hygrome sind im Kindesalter meist doppelseitig und liegen parasagittal. Durch Ausbildung von Membranen sind sie im Echoencephalogramm erfaßbar, nicht immer im bitemporalen Strahlengang, sondern oft erst bei Beschallung in biparietaler Richtung. Das ist besonders wichtig zur Erfassung kleinerer Hämatome. Ein begleitender Hydrocephalus ist nachweisbar. Verlaufsuntersuchungen erlauben eine Kontrolle der Rückbildung und Vergrößerung der Hämatome (Abb. 1).



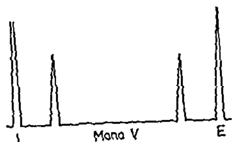


Abb 6 Monoventrikulie

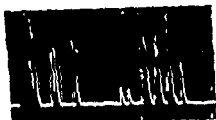








Abb 7 Ep du lham tom und Keph lhamatom b) K pl alh natom

obliterierten Gefäßen durchzogen sein können Die Erweiterung des Seiten ventrikels auf der atrophischen Seite ist meist zu erfassen Zu beachten sind die stets begleitenden Schädelasymmetrien mit unterschiedlichen Echoamplituden bei Beschallung mit gleicher Impulsstärke von beiden Seiten offensichtlich als Ausdruck der unterschiedlichen Kalottendicke

Postoperative Verlaufsuntersuchungen nach Hemisphärektomien können zur Aufdeckung von Komplikationen beitragen wie etwa ein Monroe Verschluß mit Erweiterung der Seitenventrikel der verbliebenen Hemisphäre oder Zunahme der Verlagerung des 3 Ventrikels

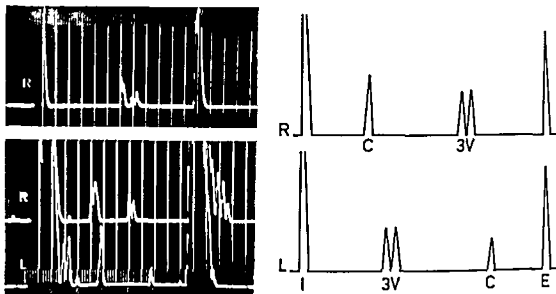


Abb. 3. Subarachnoidalcyste im Bereich der rechten Hemisphäre. (Die obere linke Echokurve zeigt bei parietalem Strahlengang die Tiefe der Cyste.)

bildung nach operativen Maßnahmen eine wirksame diagnostische Bereicherung dar. Das gilt besonders für Verlaufsbeobachtungen nach atrioventrikulärer Anastomose wegen der in diesen Fällen nicht möglichen Encephalographie (SCHIEFER, KAZNER & BRUCKNER) (Abb. 2).

Verständlicherweise ist die Differentialdiagnose eines Hydrocephalus occlusus bzw. communicans nicht möglich. Eine Ausnahme scheinen Tumoren des *3. Ventrikels und seiner Nachbarschaft zu machen*. In einem solchen Fall ließen sich die erweiterten Seitenventrikel darstellen, während eine Reflektion des 3. Ventrikels fehlte.

Für *Großhirntumoren* gelten die gleichen Verhältnisse wie beim Erwachsenen. Auf solide Tumoren ist lediglich aus der Massenverschiebung mit Verlagerung des 3. Ventrikels zu schließen. Bei zystischen Tumoren ist der Nachweis der Zyste und entsprechend die Lokalisation möglich. Große Zysten können bei günstiger Durchschallungsrichtung in ihrer Tiefe bestimmt werden (Abb. 3). Häufiger sind jedoch Zysten in einem gekammerten oder kleineren Tumor durch multiple hohe Amplituden im Echoencephalogramm charakterisiert.

Große Bedeutung hat die Echoencephalographie bei den *infantilen Encephalopathien* verschiedener Ätiologie. Bei Hemiatrophien ist das wichtigste Kriterium die Mittellinienverlagerung zur homolateralen atrophischen Seite (Abb. 4). Zystische Erweichungen, etwa nach Mediaverschluß mit Hemiatrophien, sind nicht immer im Echoencephalogramm darzustellen, da sie von

la largeur du troisième ventricule et des ventricules latéraux ainsi que par la mesure de l épaisseur du parenchyme cérébral Les tumeurs des hémisphères cérébraux se traduisent par le déplacement de l écho médian Les kystes assez volumineux sont décelables par l echo-éncephalographie Les hématrophies se traduisent par un déplacement homolatéral de l écho median Dans les traumatismes cranio-cérebraux récents l écho-encéphalographie est peu satisfaisante en raison de l apparition le plus souvent rapide de l oedème cérébral Les gros hématomes extra duraux sont décelables

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Glatt begrenzte Zysten, wie etwa eine Arachnoidalzyste oder eine Zyste des Septum pellucidum, sind leicht nachweisbar (Abb 5) Die Leistungsfähigkeit der Echoencephalographie ist gerade in diesen Fällen besonders groß So ließ sich etwa ein Fall mit Monoventrikulie nachweisen (Abb 6)

In allen akuten Fällen, etwa bei frischem *Schädelhirntrauma*, ist die Echoencephalographie weniger leistungsfähig, da im Gegensatz zum Erwachsenenalter Verlagerungen des 3 Ventrikels trotz zum Teil ausgedehnter Hämatome meist fehlen Dafür scheint das meist schnell auftretende und intensive Hirnodem verantwortlich zu sein Das epidurale Hämatomen verhält sich wie im Erwachsenenalter Das für das Kindesalter typische Kephalhämatom macht kennzeichnende Impulse nach dem Endecho (Abb 7)

Nach den bisherigen Untersuchungen kann gesagt werden, daß gerade in diesem Lebensabschnitt wegen der besonderen anatomischen und pathologischen Verhältnisse die Echoencephalographie einen wichtigen Beitrag zur Diagnose und Differentialdiagnose leisten kann

ZUSAMMENFASSUNG

Es wurden 125 Kinder mit verschiedenen cerebralen Erkrankungen echoencephalographisch untersucht Besonders günstige Voraussetzungen waren dabei atrophische und zystische Veränderungen und die anatomischen Verhältnisse des kindlichen Schädels Die subduralen Hämatome sind durch die Ausbildung von Membranen im Echoencephalogramm erfaßbar Der Hydrocephalus kann durch die Weite des 3 Ventrikels und der Seitenventrikel sowie die Messung der Hirnmanteldicke erfaßt werden Großhirntumoren sind durch Mittellinienverlagerungen gekennzeichnet Größere Zysten lassen sich im Echoencephalogramm darstellen Hemiatrophien sind durch die homolateralen Mittellinienverlagerungen erkennbar Bei frischen Schädelhirntraumen ist die Echoencephalographie wenig leistungsfähig bedingt durch das meist schnell auftretende Hirnödem Große epidurale Blutungen sind nachweisbar

SUMMARY

Echo encephalography was used in 125 children with cerebral anomalies Atrophy and cystic *conditions as well as the anatomic peculiarities of the juvenile skull* were favourable factors Due to the formation of a capsule the subdural haematomas are recognisable by this method Hydrocephalus is identifiable by enlargment of the third ventricle and the lateral ventricles and by the measurement of the cerebral cortex Cerebral tumours are recognised by displacement of the midline echo major cysts are readily diagnosable Characteristic of atrophy is displacement of the midline echo towards the affected side Due to rapidly developing cerebral oedema the method is of little value in recent cerebral injuries Major epidural haematomas are well demonstrated

RÉSUMÉ

L auteur a examiné par écho encéphalographie 125 enfants atteints de diverses affections cérébrales Les lésions atrophiques et kystiques ainsi que les caractéristiques du crane de l enfant favorisent cet examen Les hématomes sous duraux se reconnaissent sur l écho encéphalogramme grace à la formation de membranes L hydrocéphalie est reconnaissable par

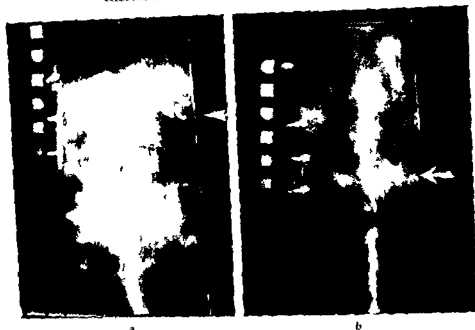


Fig. 1. Thermograms of normal low back. a) Level of posterior iliac crest (L4—L5 interspace). Long narrow vertical white stripe at *bottom* represents intergluteal cleft; diffuse patchy heat pattern with small nodular accentuations most marked *at level of L4—L5 slightly to left of midline*. b) Arrow indicates level of posterior iliac crest; nodular midline heat pattern superimposed on a diffuse midline gray zones with slight accentuation of level of L5.

surface by either evaporation of perspiration, convection by air currents or emission of infrared *radiation*, and 3) the amount of heat being absorbed by the skin *from the surrounding* environment. In order to ensure that the thermogram *reflects only the* condition of the underlying body temperature it is necessary to *let the skin* come to an equilibrium temperature with the surrounding atmosphere. This can usually be satisfactorily accomplished by exposing the part to be examined in a non drafty, cool environment of about 20 to 21 °C for at least 10 *minutes* before the thermographic scan is obtained.

Skin temperature is not *uniform* over the entire body even under ideal ambient conditions. This is *probably* in part a reflection of varying degrees of metabolic activity of *underlying tissues* and also in part a reflection of differences in the vascular *architecture of the* skin and subcutaneous region (DE SOUSA & SOVERAL RODRIGUES 1962). The surface of the body overlying large collections of adipose tissue such as *the* buttocks appears relatively cold due to the excellent insulating property of fat (HARDY 1934). The hair also is a

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THERMOGRAPHY IN NEUROLOGICAL PATIENTS

Preliminary experiences

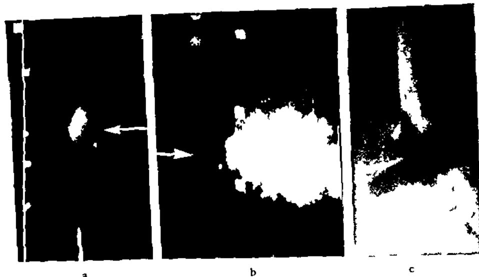
by

H. I. GOLDBERG, E. R. HEINZ and J. M. TAVERAS

The local change in temperature of the skin is utilized by most clinicians in the detection of underlying vascular, inflammatory and neoplastic disease.

Extremely sensitive heat recording instruments have recently been developed which permit rapid photographic temperature mapping of the body surface. These thermographic cameras contain thermal sensitive resistors of nickel, cobalt and magnesium oxides which respond to the infrared radiations being emitted from the surface of the body (BARNES 1963). The Barnes infrared camera used in the present evaluation employs a rapid linear scanning system which records up to 60 000 individual temperature measurements in the maximum 10 × 20 angular degree field of view covered. Since the human skin is an almost perfect emitter of infrared radiation (with an emissivity of 0.99), in the wavelengths utilized from 3 to 15 microns, the level of radiation recorded is therefore a direct function of the temperature at the surface of the body (BARNES 1963, BARNES & GERSHON-COHEN 1963, LAWSON 1957).

The normal skin temperature at any one moment is a result of many factors and may vary greatly. It depends on 1) the amount of heat conducted to the surface from the underlying tissue, 2) the amount of heat being lost from the



F g 3 B ck the mograms n patients with symptomatic malalignment of lumbar spine a) Dominant heat patte n (arrow) 5 cm above level of iliac crest in a patient with malal gnment between L3 and L4 b) Dramat c heat pattern spread ng diffusely over low back most accentuated at level of L5 (arrow) Pat ent h d a spondylolisthes s between L4 and L5 c) A severe compression of the spinal an l s p esent from dorsally th ckened l gaments and bone at level of malignment at L4—L5 Nod lar fill ng defects in p ntopaque column below the level of compression represent d lated veins secondary to the part al obstruction

gram surrounded by the large cold (dark) area represents the midline inter gluteal cleft with the adjacent buttocks which is always relatively cold due to its thick covering of adipose tissue This stripe is a useful midline orienting landmark Heated wires were placed above the skin at known distances from the iliac crest From the lowest up these were situated 5 cm below the crest at the crest 5 cm above the crest and 15 cm above the crest These markers are seen at the side of the thermograms The multiple different geometric forms also seen on the side of the scans represent a known temperature scale

A second normal heat pattern for the low back is seen in Fig 1b Here there is basically a midline increase of skin temperature which again consists of multiple nodular hot spots superimposed on a more homogeneous background The warmest and frequently the broadest accentuation of heat is usually located at the L4 and L5 level

In general therefore we found the normal low back thermogram to consist of patchy areas of increased heat with superimposed small nodular hot spots located in the midline and paraspinal region and most marked at the L4 and L5



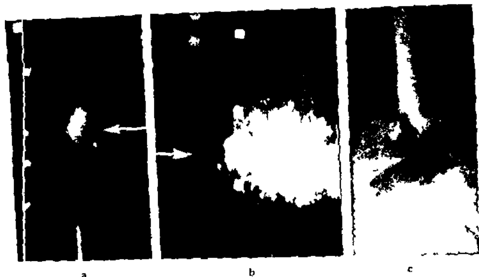
Fig 2 Thermogram of low back in patient with acute intervertebral disc herniation at L5—S1 level dominant area of increased heat at L5—S1 level (arrow)

good insulator and does not permit the transmission of skin temperature if the covering is heavy In the thermographic scans the whiter the area the warmer its relative temperature The number at the lower portion of some of the pictures indicates the sensitivity setting of the camera and defines the temperature range recorded between the pure white and the pure black regions of the film The sensitivity scale extends from 0 to 100 and indicates a temperature range on the film of 10 4° C for a setting of 0 down to 1 2 C for a setting of 100 At number 20 the gray scale range amounts to 4 1° C

Thermographic evaluation of the back and the head was carried out on a series of 75 patients at the Neurological Institute of New York and this study is being continued at the Albert Einstein Medical Center in Philadelphia Some observations will be presented on our preliminary experience with thermography in each of these two categories

Back

The heat picture of the normal back varies greatly from person to person Several general patterns and characteristics of normal heat distribution can, however, be recognized in the low back One of the common normal patterns seen was a diffuse increased heat in the midline and paraspinal area of the lumbosacral region consisting of ill defined patchy areas within which there were seen small nodular like accentuations of the heat (Fig 1a) The warmest areas were usually seen at about the level of L4 and L5 and frequently were slightly eccentrically situated The vertical white stripe at the lower end of the thermo



F g 3 Ba k thermograms in pat ents with symptomatic mal lignment of lumbar spine a) Dominant heat pattern (arrow) 5 cm above level of iliac crest in a pat ent w th malalignment bet veen I 3 and L4 b) D amat c l eat p tt rn spreading diffusely over low back most accentuated at level of L5 (arrow) Patient had a spondylol thesis between I 4 and L5 c) A severe compression of the sp nal c n l is p esent f om dorsally thi kened l gaments and bone at level of m al gnment at L4—L5 N dular filling defects in p ntopaque column below the level of comp ess on represent d lated veins secondary to the pa tial obstruct on

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Fig. 2. Thermogram of low back in patient with acute intervertebral disc herniation at L5—S1 level: dominant area of increased heat at L5—S1 level (arrow).

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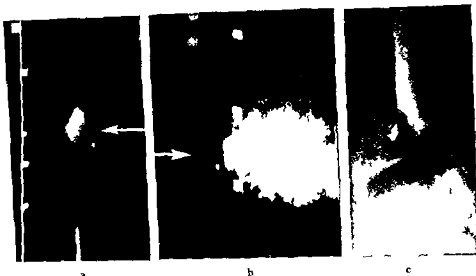


Fig 3 Back thermog ams in pat ents with sympto nat c malal gnment of lumba sp ne a) Dominant heat pattern (a row) 5 cm above level of il ac rest in a patient w th malal gnment between L3 and L4 b) D am tic heat pattern spread ng d ffusely over low back most accentuated at level of L5 (rrow) Patient had a spondylol sthes s between L4 and L5 c) A severe compression of the spinal canal is present from dorsally thickened l gaments and bone at level of mal gnment at L4—L5 Nodula filling defects n p ntopaque column below the level of compress on represent d lated veins se ondary to the part al obstruction

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Fig. 4



Fig. 5

Fig. 4. Low back thermogram in a patient with an intraspinal vascular malformation at level of L2—L3. A marked accentuation over the normal heat pattern is present in the upper lumbar region in the midline (arrow).

Fig. 5. Normal face thermogram. Symmetrical heat pattern of forehead below hair line (arrow).

levels. For a heat pattern to be considered abnormal, the thermogram had to reveal a dominant well defined hot spot which was definitely larger than the normal small nodular hot spots.

Twenty six cases with proven herniated intervertebral discs were thermographed. Only 4 of 21 lumbar herniations had what we considered to be abnormal heat patterns (Fig. 2). No cases with abnormal patterns were seen in the five herniated thoracic or cervical discs.

In a small group of patients with back pain and malalignment of the lumbar spine, pathologic thermograms were consistently present (Fig. 3). The malalignment in all four cases was secondary to degenerative intervertebral disc and posterior joint disease. On myelography in these cases various degrees of block were present due to the abnormal alignment and thickening of ligaments dorsally (Fig. 3c).

Of six cases with intraspinal and paraspinal tumors three revealed abnormal heat patterns. Two of the three positive thermograms were in patients



F g 6 Face thermogram in 26 year-old patient w th an old left supracl noid nternal carotid ar tery occlus on with collateral filling of a hypoplastic middle cereb al artery There is marked related coolness of left side of forehead (arrow)

with intradural neurofibromas that produced significant blocks on myelography The hot spots on the thermograms corresponded to the level of the myelo graphic block

An intraspinal vascular malformation produced a well localized dramatic hot spot in the low back (Fig 4) Two cases of osteomyelitis of the spine one being chronic and two cases of metastatic spinal and paraspinal malignant disease had abnormal thermograms

Three positive thermograms were encountered in symptomatic patients in whom no definite pathology could be discovered on routine radiological examination myelography or surgery

Head

Sixteen patients with diseases of the brain and skull were evaluated The results of thermography in this group are given below For satisfactory thermo

	P ui	*T t l*
Men ng oma	3	3
Int acer b al tum r	3	5
Pitu tary adenomas	1	2
Multip le scleros s	1	1
Carot d occlusion	1	1
Cerebellar tumo	0	1
Sinus mucoceles	0	2



Fig 4



Fig 5

Fig 4 Low back thermogram in a patient with an intraspinal vascular malformation at level of L2–L3 A marked accentuation over the normal heat pattern is present in the upper lumbar region in the midline (arrow)

Fig 5 Normal face thermogram Symmetrical heat pattern of forehead below hair line (arrow)

levels For a heat pattern to be considered abnormal, the thermogram had to reveal a dominant well defined hot spot which was definitely larger than the normal small nodular hot spots

Twenty six cases with proven herniated intervertebral discs were thermographed Only 4 of 21 lumbar herniations had what we considered to be abnormal heat patterns (Fig 2) No cases with abnormal patterns were seen in the five herniated thoracic or cervical discs

In a small group of patients with back pain and malalignment of the lumbar spine, pathologic thermograms were consistently present (Fig 3) The malalignment in all four cases was secondary to degenerative intervertebral disc and posterior joint disease On myelography in these cases various degrees of block were present due to the abnormal alignment and thickening of ligaments dorsally (Fig 3c)

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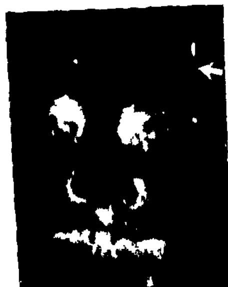


Fig 6 Face thermogram in 26-year-old patient with an old left supraclinoid internal carotid artery occlusion with collateral filling of a hypoplastic middle cerebral artery There is marked related coolness of left side of forehead (arrow)

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Intracerebral tumor	3	5
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Multiple sclerosis	1	1
Carotid occlusion	1	1
Cerebellar tumor	0	1
Sinus mucoceles	0	2



Fig. 4



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a b

Fig 8 Patient with a proven left mid suprasylvian malignant glioma a) Bilateral head thermograms showing pathologically warm region on left (arrow) above ear Compare with symmetrical area on opposite side b) Left carotid angiogram arterial phase The typical displacement of the superficial arteries (arrow) can be seen localizing the tumor to same region as the thermographic abnormality

Discussion

Increased skin temperature overlying malignant tumors of the breast as well as in other soft tissues and bone has been amply documented (BARNES & GERSHON COHEN 1963 1963, LAWSON 1957) It was somewhat surprising to find localized areas of increased back temperature when only benign underlying spinal conditions existed such as malalignment, intraspinal neurofibromata and occasionally herniated intervertebral discs In most of these abnormal back thermograms some degree of chronic block existed in the subarachnoid pathway as seen myelographically This block may in some way be related to the increased skin warmth either from alteration in the route of venous drainage or possibly from vasodilation secondary to nerve injury

The warm area of the scalp overlying some intracranial neoplasms is possibly due to the direct conduction of tumor heat secondary to increased metabolism to the surface through the calvarium In meningioma the increased surface vascularity probably contributes to the local temperature rise The decreased heat of the forehead found in the patient with the old internal carotid artery occlusion and hypoplastic middle cerebral artery appears to be related to the lower metabolic activity of the underlying poorly vascularized portion of the brain If further work shows this difference in cranial thermographic patterns between tumor and occlusive vascular disease to be consistent is valid it will be of great help in the evaluation of certain selective cases



Fig 7 Bilateral head thermogram in a patient with a large right pterional meningioma Thermogram positioned so that each side of head is facing towards middle of film Asymmetrical increased brightness on right in front of ear

grams of the head to be obtained, it was necessary to have the hair closely clipped due to the barrier the hair imposed on recording infrared radiation coming from the scalp On occasion a thermogram of the forehead provided some useful information The normal face thermogram (Fig 5) reveals a symmetrical heat pattern in the forehead region At the hair line there is a sharp cutoff to the transmission of scalp warmth

An abnormal face thermogram was encountered in a 26 year old patient with a moderate right sided weakness dating back to childhood (Fig 6) An asymmetrical coolness of the left side of the forehead was present with sparing of the paramidline region On angiography an occlusion of the supraclinoid segment of the left internal carotid artery was found with filling of a hypoplastic left middle cerebral artery through collateral circulation via the lenticulo striate arteries The external carotid circulation was normal

Three patients with meningiomas were thermographed All had abnormal heat patterns An asymmetrical hot region is seen in front of the right ear in a patient with a pterional meningioma (Fig 7)

Five patients with intracerebral tumors were evaluated Three of them showed asymmetrical heat patterns with increased warmth being recorded in the overlying scalp An asymmetrical warm area can be identified in Fig 8a on the left above and slightly in front of the ear The lateral left carotid angiogram demonstrated the vascular displacement indicating the localization of the underlying cerebral tumor which at craniotomy was found to be a glioma with malignant change (Fig 8b)

RÉSUMÉ

Les auteurs ont fait une expérimentation préliminaire avec un appareil spécial pour la mesure de la température cutanée chez des malades neurologiques atteints d'affections intracraniennes et intrarachidiennes. Certaines lésions peuvent être détectées par cette méthode. Les propriétés isolantes de la chevelure gênent considérablement la détection au niveau de la tête. Les disques intervertébraux herniés n'ont pas donné des résultats constants. Certaines tumeurs intrarachidiennes ont été détectées, ainsi que des lésions inflammatoires, néoplasiques et spondylitiques.

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Conclusions

Thermography of the spine and head was performed in the evaluation of many of the common conditions encountered in a neuroradiological clinic. The number of cases in each entity studied was too small to permit any definite conclusions. The results to date, however, have shown that thermography of the back was negative in most cases of herniated intervertebral discs. All four patients with symptomatic malalignment of the lumbar spine had abnormal hot spots on the scans. Three of six patients with intraspinal and paraspinal tumors revealed localized warm areas along with one case of an intraarachnoid spinal vascular malformation, two cases of spinal bacterial inflammatory disease and two cases of metastatic malignancy to the back. The great variability of the normal back thermographic pattern makes interpretation of possible minor abnormalities difficult.

In the head the need for completely clipping the hair restricts to a great extent its routine use in the evaluation of intracranial disease. Sixteen cases with intracranial and cranial disease were thermographed. All three surface meningiomas presented asymmetric warm areas over the tumors. Three of five intracerebral tumors were localized on the thermograms as pathologic areas with increased temperature. A case with an old internal carotid artery occlusion and secondary hypoplasia of the middle cerebral artery revealed a relative cool region of the forehead on the side of the occlusion.

Acknowledgement

Supported in part by the National Institute of Neurological Diseases and Blindness. Fellowship Numbers 2F 11NB976 02 and 2F11NB973 C2.

SUMMARY

Preliminary experiences with the use of a special apparatus for the measurement of the skin temperature in neurological patients with intracranial and intraspinal diseases is presented. It appears that certain lesions can be detected by this method. In the head the technique is severely handicapped by the insulating properties of hair. In the spine, herniated intervertebral discs have not produced consistent results. Certain tumours have been detected and inflammatory, neoplastic and spondylitic processes have also been shown.

ZUSAMMENFASSUNG

Preliminare Erfahrungen in der Anwendung einer Specialapparatur zur Messung der Hauttemperatur von neurologischen Patienten mit intrakraniellen und intraspinalen Erkrankungen werden mitgeteilt. Es scheint, dass bestimmte Erkrankungen mit dieser Methode entdeckt werden konnen. Am Schadel ist diese Technik durch die isolierenden Eigenschaften des Haares sehr beeintrachtigt. An der Wirbelsaule hat man bei Diskushernien keine einstimmigen Resultate erhalten. *Man konnte inflammatorische, neoplastische und spondylitische* Prozesse zeigen.



Fig 1 Focal ultrasonic lesion in cat brain (Courtesy of R WARWICK)

even more important, the relative immunity of the blood vessels over capillary size

In the ARSLAN technique the bone over the lateral semicircular canal is reduced to less than 0 5 mm thickness With the true focusing technique used in neurosurgery the cranial vault is temporarily removed over a wide area

The complete removal of bone alters the whole picture Instead of the absorption refraction and reflection produced by the skull vault the rays travel virtually without deviation from the transducer through a coupling bath through the membranes and brain tissue to reach a focus at a predictable site

The technical features of this procedure will be omitted here, as they will be given in a paper at the IEEE Symposium in October and most have already been published in chapter 20 of Ultrasound as a diagnostic and surgical tool The transducers used by the American workers employed a flat quartz crystal and a plastic lens The modern ceramic crystals ground to form a focusing bowl suffer from frequency instability with temperature and have not been accepted in America This disadvantage has been overcome by improved methods of monitoring and self tuning and their inherent advantages of constancy of focus position and low operating voltage can now be used without hesitation

Owing to the large solid angle of radiation employed the intensity rises very rapidly to a high level and as rapidly falls once the focus has been passed In this way it is possible to produce localized areas of cell necrosis in the brain with no overlying damage (Fig 1)

Both FRY and BALLANTINE employed a very fine thermocouple probe to identify the position of the focus This requires elaborate special equipment

FROM THE WEST END HOSPITAL FOR NEUROLOGY AND NEUROSURGERY, LONDON, ENGLAND

ULTRASONIC SURGERY OF THE CENTRAL NERVOUS SYSTEM

by

DOUGLAS GORDON

The President of the Symposium in his opening address referred to the first paper on ultrasonic diagnosis read at the 1955 Symposium in London and to the way in which the new departure had become accepted as part of neuroradiology. As the author of the 1955 paper, I now venture to suggest a subject that will become accepted by the Symposium of 1973.

Ever since the original paper, one has been tempted to look forward to the day when ultrasonic tomograms through the skull would replace the encephalogram. Nearly eleven years of experience has convinced me that the physical limitations imposed by the cranial vault make such an end result very unlikely. The future of ultrasonic tomography is in the soft tissues that are not protected by dense bone, e.g. the liver, the eye, the uterus, etc.

For the past five years I have been engaged in work on the ultrasonic destruction of the vestibular apparatus of the inner ear by the technique first invented by ARSLAN (1964). His position as the "Father of Ultrasonic Surgery" is as unique as that of DUSSIK in ultrasonic diagnosis.

The use of highly focused ultrasound has been developed in the U.S.A. by FRY and his colleagues, by MEYERS and by LELE & BASAURI. These investigators established the remarkable sensitivity of nerve tissue to ultrasound and,

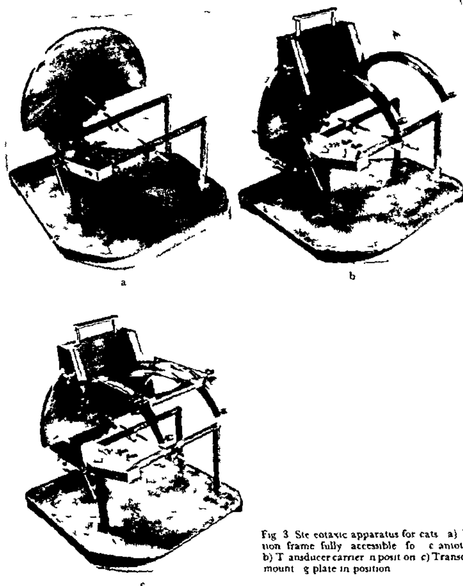


Fig 3 Stereotaxic apparatus for cats a) Fixation frame fully accessible for craniotomy b) Transducer carrier in position c) Transducer mounting plate in position

the surface of the hemispheres but even to identify the position of the sagittal sinus to a matter of thousandths of an inch (fortieths of a millimeter) Further it has been possible to measure with similar accuracy the distance from the top of the lateral ventricle to the surface of the cortex above it

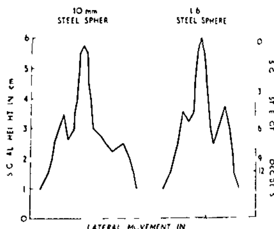


Fig 2 Echo amplitude with lateral scan at level of focus (diameter 10 cm focal length transducer 10 cm) showing the slight effect *obtained by altering size of target sphere*

beyond the available funds It was however essential to identify the position of the focus with accuracy To do this biologically is very difficult It was however realised that ultrasonic pulse techniques could be used for this purpose by the simple device of using a steel sphere as target The bowl transducer is connected to a standard Sperry reflectoscope or echo encephalograph and the steel sphere is supported by a fine wire attached on the far side

When the center of the sphere corresponds to the center of the focus, the rays all strike the surface of the sphere normally and are reflected back on their track With the slightest displacement the angulation ceases to be optimum and the echo signal falls greatly Strangely enough, there is hardly any effect on the accuracy if a sphere of 1 6 mm diameter is replaced by one 10 0 mm in diameter (Fig 2)

The extreme precision of this measurement will explain why the focussing can be so good that LELE has produced lesions as small as 50 nerve cells

The use of the focused transducer and the reflectoscope had proved so satisfactory in calibration that it was decided to use it during the course of an animal operation It is possible to obtain large echo signals from a very small structure at the focus, but large structures elsewhere in the beam part gave no detectable signals By restricting observation to the signals obtained from the focal area it was possible to map out the anatomy of the upper surface of the brain at the first attempt, using a British flaw detector The pulse length was however so long that no deeper structure could be detected It was thought necessary to employ a special damped transducer to obtain short enough pulses

Very recently however the Sperry reflectoscope became available and it was found possible with this to obtain short enough pulses from the standard undamped bowl transducer Two cats have been operated upon with the latest equipment and in each case it has been possible not merely to identify

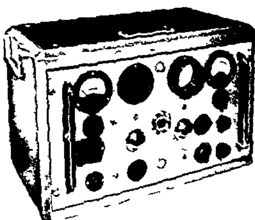


Fig 6 Ultrasonic power generator for lesion making

antero posterior plane and by a mounting plate that slides over the curved arms to give lateral angulation These movements are arranged to produce no shift of the focus relative to the semicular plate (Fig 3b and c)

Into the recess in the mounting plate can be put a pointer that indicates the position of the focus 15 cm from the center of the 15 cm diameter circle All the transducers are adjusted to have their foci at the same point relative to the recess If necessary the pointer can be introduced first to indicate the site of the focus and a series of readings taken on the scales that indicate the position of the focus according to Horsley Clark Cartesian co-ordinates If the position of the sagittal sinus is known relative to the ear bars the brain size can be determined (Figs 4 and 5)

Alternatively the transducer can be inserted and the sinus located ultrasonically In the complete equipment a parallelogram pantograph will be attached to the baseplate and to the transducer place and the other end will move a pointer over the teledeltos paper In this way a magnified tomogram will be produced from which the site of the tissue to be destroyed can be determined The transducer is moved to bring the focus to the site and its cable is then connected to a power generator to produce the lesions Each lesion will be recorded automatically on the same teledeltos paper

The results of stereotaxic surgery in Parkinsonism using the Bennett apparatus are so good that it is not suggested that ultrasound should be used to attack the globus pallidus The scope foreseen for the new technique is immediately in neurophysiology and later in tractotomy of the cord the reduction in size of gliomata of the dominant hemisphere and in attacking tumors in the pons and other surgically inaccessible sites Only time will show the value and limitations of this new technique

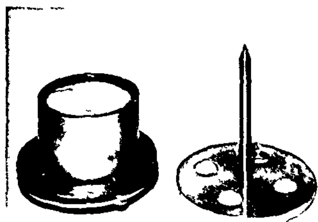


Fig. 4. Pointer and transducer for stereotaxic apparatus. Center of curvature of concave transducer has the same relation to the mount as the pointer tip. Aperture in transducer is for saline circulation.

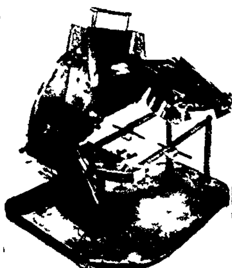


Fig. 5. Transducer in position in the mounting plate.

The application of this degree of precision to the localisation of an electrode within the brain stem is obvious. There are however other commoner applications. The new equipment, when complete, will permit the automatic recording of magnified coronal or sagittal cross sections of the brain or spinal cord through the unopened dura.

Electronically it is a simple matter to select only those echo signals that occur at the focus, to amplify them and make them record on teledeltos paper. It is already possible to obtain suitable signals from the cortex and ventricles but with further developments it may well be possible to detect the interfaces between grey and white matter.

Technique. While performing the craniotomy only the semicircular transducer plate is in position (Fig. 3a). When sufficient access has been obtained the frontal sinuses, if opened, are sealed with bone wax and a sponge rubber gasket makes a water tight seal between the skull and under surface of a plate with a central aperture.

A saline reservoir is provided by using nylon film and rings of clear perspex (lucite) to construct a bath of sufficient height. The nylon is clamped to the edge of the opening in the plate so that degassed saline can fill the space between the dura and the transducer.

The transducer is supported by a carrier that provides angulation in the

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Acknowledgements

This work was made possible through the Clinical Research Fund of the North West Metropolitan Board of the National Health Service Technical assistance from Dr H C Grant in performing the neurohistologic investigations and from the Sperry Products Co for the modified reflectoscope have been invaluable, thanks are also due to the Paddington General Hospital staff for animal operation facilities

SUMMARY

Highly focused ultrasonic transducers have been developed using ceramic piezo electric materials which can be employed to produce sharply defined trackless focal lesions in the central nervous system Ways have been found to use the same transducers with an echo technique to establish the internal anatomy of the brain with high accuracy Steel spheres in water baths permit the accuracy of focusing of the transducer to be established The size of the steel sphere is unimportant Automatic recording of the anatomy in cross section in enlarged form is being planned

ZUSAMMENFASSUNG

Stark fokusierte Ultraschallstrahler sind unter Verwendung von keramischem piezoelektrischem Material mit dem man scharf umschriebene narbenlose fokale Veränderungen im ZNS erzeugen kann entwickelt worden Es wurden Wege gefunden dieselben Strahler bei Echo Technik zu verwenden um die innere Gehirnanatomie mit grosser Genauigkeit bestimmen zu konnen Stahlkugeln im Wasserbad gestatten eine genaue Fokusierung der Strahler Die Grosse der Stahlkugeln ist nicht von Bedeutung Automatische Registrierung von anatomischen Querschnitten in vergrosserter Form ist geplant

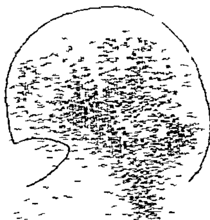
RÉSUMÉ

Des matériaux céramiques piézo électriques ont permis de fabriquer des transducteurs ultrasoniques très focalisés que l on peut utiliser pour créer des lésions focales a limites nettes dans le système nerveux central On a trouvé le moyen d utiliser ces mêmes transducteurs par une technique d écho pour établir avec une haute précision l anatomie interne du cerveau La précision de la focalisation du transducteur peut être appréciée au moyen de sphères d acier placées dans l eau Le diamètre de la sphère d acier est sans importance L auteur a le projet de faire des enregistrements automatiques en coupes agrandies de régions anatomiques

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Fg 1 Dlatation de la part e ntracranienne d la grande citerne (meg citerne) sans atrophie cérébelleuse verifee par encephalographie gazeuse fract onnée Forte rad o-acti ite du p le poster eu de la fo se poster eure



Fg 2 Atroph e m dulla re diffuse ver fiee par myelographie gazeu e Homogeneisat on du cont aste sc nt graphiqu sur toute l etendue du ach (5 h après inj ct on de 200 microcuries de RISA)

superposable dans les cas d obstacle partiel Le methiodal et la RIS A marquent en effet un arret complet devant un obstacle incomplet alors que le contraste lourd (lipiodol) montre la persistance d un passage au niveau de tels obstacles partiels Dans un cas nous avons constate d autre part que la diffusion de la sérum albumine était bloquee devant un obstacle cervical egalement incomplet dans ce cas le contraste aerien franchissait cet obstacle en délimitant parfaitement l opacité tumorale (meningiome cervical)

Les atrophies cerebrales corticales sont bien objectivees par l importance de la radio activité des espaces pericerébraux Il en est ainsi pour les atrophies diffuses et pour les atrophies localisées Le scintigramme lateral de la fosse postérieure est assez variable car on observe une radioactivite toujours importante au niveau des citernes pre bulboprepontiques avec une diffusion tres inconstante dans la grande citerne Les cas de megaciterne non pathologique

SERVICE CENTRAL DE RADIOLOGIE (DIR. PROF. CH. M. GROS) ET CLINIQUE NEUROLOGIQUE (DIR. PROF. F. THIEBAUT) DU C.H.U. DE STRASBOURG

SCINTIGRAPHIE CISTERNALE

par

CH. M. GROS, A. WACKENHEIM, C. VROUSOS et M. SUBIRANA

Nous avons présenté ailleurs nos premiers résultats de scintigraphie cisternale obtenue par scanning avec le nucléographe de Siemens. Actuellement nous disposons de 60 examens scintigraphiques tant du canal rachidien que des citernes intracraniennes après injection lombaire de 200 microcuries de sérum albumine humaine marquée à l'^{131}I.

L'examen scintigraphique, bien que soumis à des servitudes techniques résultant de la longueur du temps d'enregistrement et de l'imprécision morphologique inhérente aux méthodes actuelles, semble néanmoins devenir un examen de routine. Les neurologues et neurochirurgiens sont encore peu orientés vers ce type d'examen en raison de la multiplicité des autres moyens d'investigation radiologique mis à leur disposition.

Notre matériel est très homogène quant à la technique d'application. Nous avons toujours procédé aux scintigrammes 5 heures après injection lombaire. Il est évident que l'exploration fonctionnelle et morphologique approfondie devrait comprendre des enregistrements répétés dans le temps. Dans ce travail, nous tenons à préciser quelques points particuliers observés sur ce matériel de 60 cas.

Des examens scintigraphiques confrontés avec les données du contraste hydrosoluble nous ont permis de constater qu'ils avaient un comportement

Fig. 4. Hématome péricérébral droit du nourrisson (injection par la fontanelle antérieure). *En haut* : Grande cavité parasagittale s'étendant dans la fosse cérébrale moyenne. *En bas* : (Dix jours après ponction évacuatrice). Persistance d'une cavité pariéto-occipitale. Les parties frontale et basale de l'hématome ont disparu.

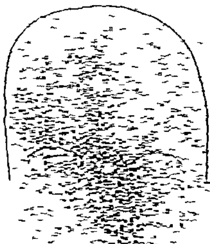


Fig. 5. Masse expansive frontale gauche (glioblastome). Exclusion de la citerne sylvienne gauche. Déviation des citernes sagittales vers la droite.

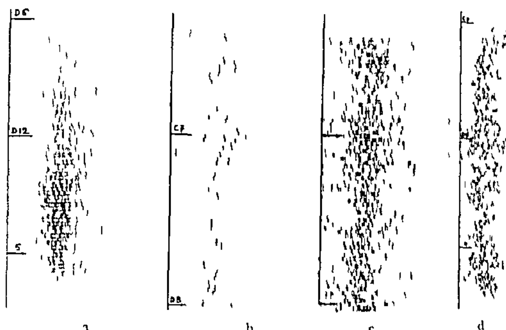


Fig. 3. Forte diminution de la radio activité cervico dorsale vraisemblablement en rapport avec la position en procubitus pendant l'examen. a) Forte radio activité du segment lombaire. b) Faible radio activité cervico dorsale (conditions d'enregistrement identiques qu'en (a). c) Enregistrement de toutes les impulsions de la région cervico dorsales. d) Elargissement de l'image scintigraphique des régions dorsolombo sacrée avec faux arrêt au niveau de C7 (injection lombaire). Ce trouble de la diffusion constaté 5 h après l'injection semble dû à la diffusion latérale du radio élément.

se caractérisent par une forte activité de la région occipitale postérieure et ne peuvent pas être interprétés comme signe d'atrophie cérébelleuse. L'étendue de la tente du cervelet est toujours bien dessinée.

Les cas d'atrophie médullaire sont moins explicites. Dans un cas d'atrophie médullaire segmentaire vérifiée chirurgicalement, nous avons observé une hyperactivité nettement localisée dans le segment atrophique. Dans un cas d'atrophie médullaire diffuse vérifiée par myélographie gazeuse, nous avons observé une nette homogénéisation du noircissement sur l'ensemble du canal rachidien.

Dans 4 de nos 60 cas, il existait une très nette diminution de la radio activité cervico dorsale qui pose a priori le problème d'un rétrécissement du canal rachidien ou d'une hypertrophie diffuse du cordon médullaire. Dans aucun de ces 4 cas, nous n'avons pu vérifier l'une de ces hypothèses. Cette répartition hétérogène semble être en rapport avec la moindre quantité du liquide céphalo rachidien dans la région dorsale en position de procubitus, que nous avons fait adopter à nos malades dans cette première série d'examens.

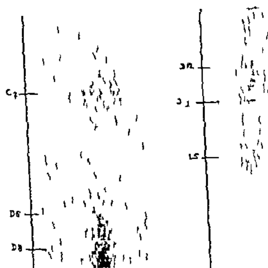


Fig 7 Suspicion d'arachnoïdite spinale après méningite purulente (malade du Professeur G ARNOULD Nancy) A gauche Arrêt à la hauteur de D6 marquant un blocage qui est incomplet car on note une certaine activité au niveau de C 7 A droite Nette hypoactivité au niveau de la queue de cheval

s avère très utile pour la délimitation beaucoup plus précis et plus élégant que la méthode pneumographique Cette dernière nécessite en effet de nombreux clichés dans les différentes positions et souffre des rapports hydroaériques alors que le radio élément diffuse dans l épanchement proprement dit en réalisant un mélange homogène Les contrôles scintigraphiques après ponction ou intervention permettent de suivre l extension du volume de la cavité Dans deux cas nous avons été frappés par l extension de ces épanchements péricérébraux du nourris on vers la base du crâne au niveau du pôle antérieur de la fosse cérébrale moyenne

Nous n insistons pas sur la facilité du diagnostic scintigraphique de déviation du plan sagittal médian lorsqu il s agit de processus expansifs hémisphériques d une certaine taille Les modifications scintigraphiques directes sous forme de zone froide ou tiède sont bien entendu plus difficiles à reconnaître tant de face que de profil L exclusion de certaines citernes viendra toutefois renforcer les possibilités de diagnostic

La scintigraphie cisternale s avère particulièrement intéressante dans les cas de blocage arachnoïdien La diffusion du radio élément se fait toujours très nettement dans les citernes basales Le blocage de ces citernes s accom

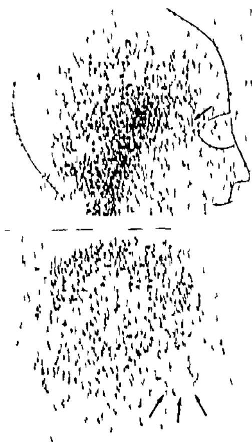


Fig. 6. Rhinorrhée cérébro-spinale spontanée par fistule de la partie antérieure droite de la lame criblée. *En haut*: L'alignement de quelques symboles indique le siège de la fistule (⟶) sur le scintigramme de la 5e h. *En bas*: Après 24 h le radio-élément intracrânien a diffusé dans les citernes basales antérieures et parasagittales. Il existe en outre un renforcement de la radio-activité dans la région ethmoïdale par l'accumulation de L.C.R. radioactif (⟶).

Dans 5 cas nous observons un élargissement anormal du scintigramme rachidien. Cet élargissement est particulièrement prononcé dans la région lombaire. Dans 1 de ces cas la diffusion du radio-élément est arrêtée à la hauteur de C7. Il s'agissait d'un faux arrêt, la myélo-radio-cinématographie ayant démontré l'absence d'obstacle avec des signes de protrusion discale cervicale. Le faux arrêt enregistré à la 5e heure est probablement en rapport avec la diffusion latérale du radio-élément. Il semble d'ailleurs que dans 3 autres cas d'élargissement scintigraphique du canal rachidien il s'agissait de diffusion latérale (radiculaire ?) du radio-élément. Dans une seule de nos 5 observations de dilatation scintigraphique transversale du canal rachidien lombaire nous avons pu constater une image saccoradiculographique de dilatation du fourreau sous-arachnoïdien lombaire avec kystes radiculaires. L'exploration scintigraphique des arachnoïdites spinales s'avère particulièrement intéressante, car elle permet de localiser des zones lacunaires d'hypoactivité ainsi que les blocages.

Dans les cas d'épanchements sanguins péri-cérébraux du nourrisson (nous avons étudié trois malades), l'injection du radio-élément par le bregma

schen Subtentoriale Tumoren der Hemispharen des Kleinhirnes zeigen die Verschiebung der Mittelinie nach der gegensatzlichen Seite in Szintillogramm Ebenso kann die Ausweitung der Cysternen bei Kleinhirnatrophie und Stenosen bei Arachnoiditis erkannt werden Fisteln zwischen dem Gehirn und dem Gesichtsschadel zeigen die radioaktive Hyperaktivitat in der Linie der Fistel und moglicherweise in den Lufthohlen des Gesichts schadels Die Fullung des Subduralraumes mit radioaktiven Stoffen ist die Methode der Wahl fur die Aufzeigung der Ausdehnung der subduralen Hamatome im Kindesalter

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pagne d'un arrêt de la diffusion que nous avons observé dans un cas suspect d'arachnoïdite basale.

L'étude radiologique des rhinorrhées céphalorachidiennes est toujours particulièrement difficile. Les radioisotopes permettent naturellement de confirmer la radio-activité de l'écoulement nasal après injection lombaire du radio-élément. L'étude scintigraphique nous a permis de déterminer en outre le siège approximatif de la fistule. La densité des symboles est toutefois difficile à reconnaître au niveau du trajet fistuleux en raison de l'importance de la radio-activité des citernes basales. Après 24 heures, nous avons observé une nette hyperactivité de la face, en rapport avec l'envahissement des cavités ethmoïdo-nasales par la RISA du liquide céphalo-rachidien.

RÉSUMÉ

Les obstacles dans le canal rachidien sont facilement mis en évidence par la scintigraphie des espaces sous-arachnoïdiens. En dehors de ces obstacles, on rencontre des images très intéressantes de rétrécissement du canal rachidien. Lorsque le radioélément diffuse latéralement dans le poches radiculaires, on peut observer des ralentissements de la diffusion qui simulent des arrêts. Dans les tumeurs hémisphériques soustentorielles, la déviation contro-latérale du plan sagittal médian est repérée sur le scintigramme. La dilatation cisternale des cas d'atrophie cérébrale, les arrêts, d'hypo-activité et sténoses des arachnoïdites spinales sont également bien visibles. Les fistules liquidiennes cranio-faciales se caractérisent d'une part par l'hyperactivité du trajet fistuleux et d'autre part par la radio-activité secondaire des cavités pneumatiques de la face. La sous-durographie est l'examen de choix pour délimiter les cavités d'hématome sous-dural du nourrisson.

SUMMARY

Obstructions in the vertebral canal are readily demonstrated by scintiscanning of the subarachnoid spaces. In addition to such obstruction interesting evidence of narrowing of the spinal canal may be encountered. When the radio-element diffuses laterally in the root sleeves, a slowing of the diffusion simulating arrest may be observed. In subtentorial tumours of the hemispheres the contralateral deviation of the median sagittal plane is shown on the scintigram. Cisternal dilatation in patients with cerebral atrophy, arrested hypo-activity and stenoses in spinal arachnoiditis are also well demonstrated. Craniofacial fistulas are characterized on the one hand by hyperactivity of the fistular outline and on the other hand by secondary radio-activity of the facial air cavities. Subdurography is the examination of choice for delineating the cavities of subdural hematomas in infants.

ZUSAMMENFASSUNG

Verschlüsse des Wirbelkanals können leicht durch Scintillographische Untersuchung des Subarachnoidalraumes erkannt werden. Auch wichtige Information über eine Verengung dieses Raumes kann festgestellt werden. Die Diffusion des radioaktiven Elementes lateralwärts in die Ärmel der Nervenwurzeln geht langsam von statten und kann Verschluss vortäu

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PALENCEPHALOGRAPHY

by

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Palencephalography is a method which can be applied for neurological diagnosis in the same manner as electroencephalography echoencephalography or other non specific types of localizing measures The term originates from the Greek *παλλω* which can be translated to mean oscillation, pulsation or vibration Attempts are being made through the analysis of the records acquired through palencephalography to approach a pathologic as well as a topographic diagnosis

More than a decade ago a series of studies was made by the school of BARCIA GOYANES which followed the thesis of CALVO in 1950 concerning the vascular structures of cerebral tumors They directed their studies to an interpretation of the vibrations which were recorded from various parts of the head with a microphone and they gave the name palencephalogram to the record obtained After determining the appearance of the normal record they first studied the tracings in patients with intracranial tumors and intracranial hematomas Later they studied the conditions found with abnormalities of the circulatory system such as *arteriovenous* fistulae arterioscelerosis and hypertension, they also studied the records of *psychotics* Since this work has not been corroborated by published reports from any other clinics we have undertaken the present study which has dealt *principally* with intracranial tumors subdural hematomas intracerebral hematomas and arteriovenous fistulae We have in

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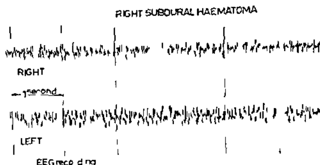


Fig 3 Palencephalogram of a right subdural hematoma showing diminution of amplitude as compared with normal left side

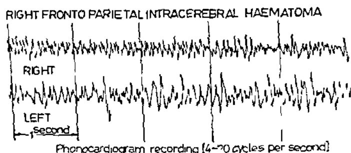


Fig 4 Palencephalogram (recorded with a phonocardiograph) of a right intracerebral hematoma showing diminution of amplitude as compared with opposite side

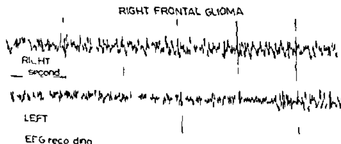


Fig 5 Palencephalogram of a right frontal glioblastoma Note greater amplitude and distortion of waves (slowing and irregularity) as compared with *left side*

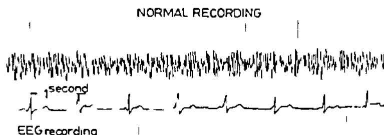


Fig 1 Normal palencephalogram recorded with electroencephalograph showing fusiform configuration of tracing with a frequency of 18 to 20 per sec in relation to cardiac activity (EKG)

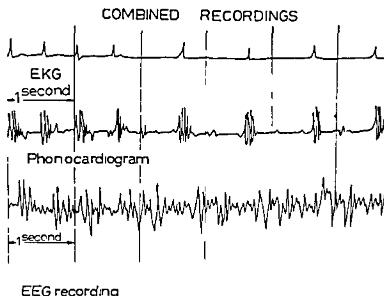


Fig 2 Normal palencephalogram recorded with electroencephalograph for comparison with the different configuration of the EKG and phonocardiogram showing their time relationships

some measure found comparable results, but do not feel that we can be as categorical in our report at this time as they have been

The technique consists in the application of a microphone to various parts of the head and the recording of the vibration by means of a phonocardiograph or by electroencephalography It is most important that the patient be at ease during the recording since emotional states cause artifacts due to an increase in the heart rate which can result in an increase of the frequency, amplitude and configuration of the waves In addition to being quiet the patient should *not* swallow nor should there be any movement of his teeth, as these activities cause a high wave to be recorded Records are run from various parts of the head and over comparable positions of both hemispheres

The vibrations are recorded as tracings of waves which are rhythmical

RIGHT OCCIPITAL ARTERIOVENOUS MALFORMATION
before operation

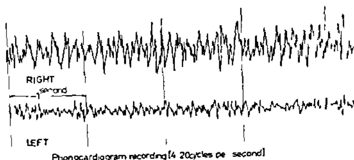


Fig 8 Palencephalogram of a right occipital arteriovenous malformation (recorded with phonocardiograph) demonstrating increased amplitude and slowing of frequency as well as distortion of configuration of waves as compared to left side

RIGHT OCCIPITAL ARTERIOVENOUS MALFORMATION
after operation

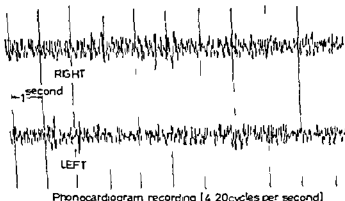


Fig 9 Palencephalogram of same case as in fig 8 after operation showing recovery toward normal pattern by diminution of amplitude and less distortion of waves compared with fig 8 The frequency is the same as the left side and the distortion is minimal

tumors meningiomas and arteriovenous malformations We have also noted that there is a greater regularity to the amplitude of the waves with meningiomas than with these other processes which show a more variable spiky character

These characteristics can best be considered by the presentation of typical tracings associated with various types of intracranial pathology as seen in Figs 1 to 9

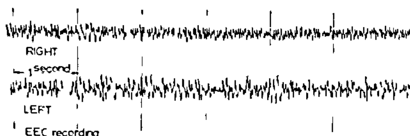


Fig 6 Paleencephalogram of a left parietal metastatic bronchogenic adenocarcinoma showing greater amplitude slowing and irregularity of waves compared with right side

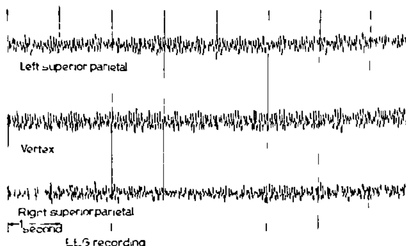


Fig 7 Paleencephalogram of a left parietal parasagittal meningioma showing some increase of amplitude compared with right side Note absence of fusiform morphopology on left side compared to right There is no distortion of the morphopology of the tracing as seen in that of glioblastoma in fig 5

are related to the cardiac cycle, have a frequency of 5 to 20 cycles per second and an amplitude which is variable, being high in the frontal regions, of medium grade in the *mid temporal* and *parietal regions* and *low in the occipital* region The frequency is also highest in the frontal region, reaching 20 per second, and is about 10 in the other regions

We have found that the amplitude is the more diagnostic feature of the record, and with a subdural hematoma the amplitude is depressed over the site of the hematoma This is also true with intracerebral hematomas On the other hand the amplitude with gliomas is increased, as it also is with metastatic

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RAPID BRAIN SCANNING WITH TECHNETIUM 99m

by

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Brain scanning for the diagnosis and localization of focal neurological disease is a well established adjunctive procedure in modern clinical practice All forms of scanning however are limited on one hand, by the radiation dosage to the patient from the administered isotope and on the other by the prolonged scanning time and relatively poor resolution of the resulting picture Nevertheless the innocuous nature of the procedure as compared to angiography and pneumography appears to warrant continued efforts to overcome these limitations The present report describes preliminary results of a combined attack on various aspects of this problem

The limitations of scanning are obviously reciprocal in nature By doubling the isotope dosage one may reduce the scanning time to half or by sharpening the resolution of the collimator detector one may improve the resulting picture at the expense of sensitivity In our minds the prolonged time especially when multiple views are required represents the most serious practical limitation to brain scanning This is especially true in patients with brain tumors who are frequently very ill disoriented and unable to cooperate The factors considered in the present approach were (1) improvement of

SUMMARY

Palencephalography is a non specific method of cerebral localization which depends on picking up the non audible vibrations from the head by means of a microphone and recording them as tracings with an electroencephalograph The method has been useful in localizing intracranial tumors hematomas cysts abscesses and arteriovenous malformations

ZUSAMMENFASSUNG

Palencephalographie ist eine unspezifische Methode fur die Gehirnlokalisierung die auf den Empfang der unhorbaren Vibrationen des Kopfes mit Hilfe eines Mikrophones und deren Aufzeichnung in Form von Kurven mit einem Elektroencephalograph beruht Diese Methode ist bei der Lokalisierung von intrakraniellen Tumoren Hamatomen Zysten Abszessen und arteriovenösen Missbildung von Nutzen gewesen

RÉSUMÉ

La pallencéphalographie est une méthode non spécifique de localisation cérébrale basée sur la réception des vibrations inaudibles de la tête par un microphone et leur enregistrement sous forme de tracé par un électro encéphalographe Cette méthode a été utile pour localiser des tumeurs intracraniennes des hématomes des kystes des abcès et des malformations artérioveineuses

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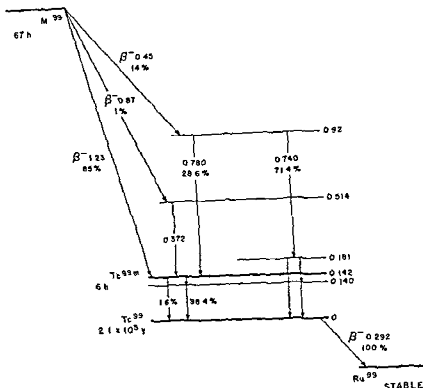


Fig 3 Decay scheme of molybdenum 99

ity for specific gamma energies The shape of the collimator field of view has been introduced as a design parameter making it possible to design collimator which provide spatial resolution that is approximately independent of the distance from the collimator face to the midline of the patient s head (BECK 1964) All scans presented in this study were performed with such collimators using 4 inch focal length and 1 inch diameter of view

In addition the time wasted in scanning empty space' beyond the patient s head is minimized by an interrupted light beam system which consists of small light bulbs in the center holes of collimators on one side of the patient s head focused on photodiodes in the center holes of the opposite collimators Signals from this system reverse the scan direction and produce marks on the film record to outline the patient s head

The system utilizes no background erase count down 'contrast enhancement or rate meter circuitry involving a time lag Thus it is possible to scan



Figs. 1 and 2. Brain scanner designed at the Argonne Cancer Research Hospital showing opposed pairs of detectors, plastic sling for head, and the four channel electronic assembly and scan control console on right with patient in position for lateral scans, and for frontal and occipital scans respectively.

mechanical design to permit rapid and more efficient scanning, (2) the use of an optimized detector collimator assembly to increase the detection sensitivity and resolution, and (3) the use of ^{99m}Tc as pertechnetate as the radioisotope to reduce radiation dosage to the patient and to increase the available number of detectable photons.

The scanning system used in this study was designed and constructed at the Argonne Cancer Research Hospital under the supervision of two of the authors (R. N. B. and D. B. C.) who were in daily consultation with a third (P. V. H.). Although a theoretical study (BECK 1961) had indicated the efficacy of gamma energies below 200 keV, and that the optimum energy is closer to 100 keV (HARPER et coll. 1964), isotopes such as ^{99m}Tc (140 keV) were not in use for brain scanning when the detectors were designed. The instrument was therefore designed as a research tool with detector shielding adequate for gamma energies up to at least 364 keV (^{131}I). Many of the techniques incorporated in this system were developed in a pilot study which resulted in the construction of a small animal scanner (BECK & CHARLESTON 1964).

The ACRH brain scanner (Figs. 1 and 2) was designed to produce simultaneous left and right lateral scans of conventional quality (or a. p. and p. a. scans) in as little as 90 seconds. This short scanning time is made possible by a combination of factors. The time is reduced by a factor of approximately four by use of four scintillation detectors arranged in opposing pairs, which scan both sides of the patient's head simultaneously.

Since good spatial resolution requires that collimator septa be thick enough to permit only negligible penetration of gamma rays, these detectors have been designed to accept interchangeable collimators which have maximum sensitiv-

(HVL in lead 0 026 cm) The daughter activity of ^{99m}Tc is technetium 99, whose radioactivity is negligible, being 3 3 × 10^{-6} μCi per millicurie of ^{99m}Tc destroyed or 3 3 × 10^{-5} μCi per millicurie of ^{99}Mo destroyed Technetium 99 decays by emitting a soft (0 29 MeV) beta to stable ruthenium 99

Technetium 99m generators are currently available from Brookhaven National Laboratory at reasonable cost (Fig 4) The daughter isotope is eluted from the generator with 0 1 N HCl This solution may be sterilized and used directly with or without neutralization or processed further if desired (HARPER et coll 1964)

The distribution of pertechnetate in the body is superficially very similar to that of iodide It is distributed rapidly in the extracellular space and is selectively localized in the stomach salivary glands and thyroid from which it may be displaced by chemical competition by I^-, or more effectively by ClO_4^- The brain tumor ratio is almost identical to that of neohydrin (McAFEE & FUEGER 1964) and it is selectively excluded from the cerebrospinal fluid Studies in mice show 90 % excretion of intravenously administered pertechnetate in the first 24 hours with a considerably slower excretion rate of the remaining fraction Human studies show that approximately one half of the injected ^{99}Tc activity is excreted in the first 48 hours after intravenous administration of the material as pertechnetate Unlike radioiodide intestinal excretion of the ^{99}Tc activity forms a substantial fraction of the total excretion These studies are being published in detail elsewhere

In the present study pertechnetate was used as an extracellular space tag similar to gallium 68 EDTA (ANGER & GOTTSCHALK 1963) While satisfactory brain scans may be obtained after oral administration of the isotope, higher blood levels and higher count rates are achieved with intravenous administration After intravenous injection of pertechnetate ^{99m}Tc has a disappearance curve from the blood with an initial rapid component whose half time is approximately 15 minutes This probably represents equilibration with the extracellular space The remaining ^{99m}Tc has a blood disappearance half time of approximately 3 hours These two components are of approximately equal magnitude Injection of 1 0 gm NaI with the pertechnetate does not significantly alter this pattern While administration of the isotope alone gives satisfactory brain scans it has been our practice to give 1 0 gm of NaI to reduce the specific localization in the stomach thyroid and salivary glands It is possible that the administration of perchlorate would be more efficient as 1 0 gm perchlorate abolishes this localization completely making more isotope available for the scan The radiation dosage from the usual scanning dose of 10 to 12 mCi of ^{99}Tc assuming complete retention and uniform distribution is approximately 100 m rad to the total body and approximately 3 000 m rad

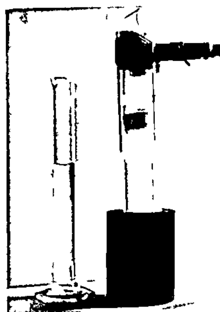


Fig. 4. Technetium 99m generator as prepared by Hot Lab Division, Brookhaven National Laboratory, Upton, Long Island, New York.

at high speed (2.5 cm/sec) without producing 'scalloping'. Artifacts such as line and spot structure are minimized by using a small index width between scan lines and by recording bell shaped spots which overlap smoothly (CHARLESTON & BECK 1964).

The reduction of the radiation dosage to the patient by choice of a more suitable radioactive material has probably made the largest contribution to the present method, although without the concurrent improvements in the scanning mechanism, much of this advantage would be lost. The advantage of a short effective half time in reducing the radiation dosage to the patient is obvious, and this factor has led to the very general use in brain scanning of neohydrin tagged with mercury 203 or 197. The rapid excretion of the agent is the controlling factor in this case. To reduce the effective half time by using a material of short physical half life introduces severe logistical problems which in certain cases, including the present study, are met by using a generator or 'cow' from which the short lived daughter isotope is eluted or 'milked' from a longer lived parent. Gallium 68 is produced in this way from germanium 68 (YANO & ANGER 1964). Similarly technetium 99m, whose half life is 6 hours, is produced from 2.8 day molybdenum 99 (Fig. 3).

Technetium 99m has the additional advantage that it produces no primary particle radiation so that the energy deposited in tissue is small. The E_β is 0.014 MeV and includes the effects of conversion electrons and soft γ and fluorescent photons. The I_γ is 0.56 R/hr at 1 cm. The principal 140 keV γ (0.92/disintegration) penetrates tissue well (HVL 4.5 cm) and is shielded easily



Fig 6 Ninety second lateral scan of same patient as in fig 5 1/4 inch ride (Reprinted from Nucleonics Vol 22 pp 50—54 January 1964 with permission of McGraw Hill and Company)

showed no abnormal uptake but a lesion was in fact discovered on radio logical surgical or postmortem study of the patient Scans were considered technically unsatisfactory when not interpretable for technical reasons The definite categories were those in which the clinical correlation was precise They include those patients in whom neuroradiologic procedures or operative intervention denoted with clarity the presence or absence of a lesion In several patients suspected lesions were confirmed at post mortem examina tion The probable categories contain scans of patients in whom on clinical grounds the presence or absence of lesions was known with a fair degree of certainty although operative or autopsy confirmation was not obtainable These results are summarized below

Category	Definite	Probable	Total
Positive	63	5	68
Negative	78	10	88
False positive	2	4	6
False negative	8	2	10
Technically unsatisfactory			10
			182

In this series 38 patients had neoplasms of the brain verified either by an unequivocal neuroradiologic examination a positive operative approach or a confirmatory post mortem examination The correlation between the scan interpretations and verified neoplasms is shown on the following page



Fig. 5. Fifteen minute lateral scans of patient with a glioblastoma of the left parietal lobe. 1/16 inch index. 10 mCi $^{99m}TcO_4^-$. (Reprinted from Nucleonics, Vol. 22, pp. 50—54, January 1964, with permission of McGraw-Hill and Company.)

to the stomach which is the target organ. It has been our practice to begin scanning 15 minutes after injection of the isotope, allowing time for equilibration between the intravascular and extravascular compartments. The usual scanning time for each pair of lateral or frontal occipital scans is 10 to 15 minutes, so that the whole procedure takes about one hour per patient, including injection, set up time, and developing.

Results

The method described above was used to make brain scans on 175 patients from August 1, 1963 through July 1, 1964. Several patients were scanned more than once making a total of 182 runs, or 738 scans (4 or more scans for each patient). Scans were classified into five main categories: positive, negative, false positive, false negative, and technically unsatisfactory, and each category was further subdivided into definite and probable. Scans were called positive when abnormalities in distribution of the radioactivity corresponded to radiological, operative, or autopsy findings. Negative scans were those with no evidence of abnormal uptake, and were in agreement with clinical findings for absence of any focal lesion. A scan was classified as false positive when abnormal concentration of the isotope suggested a focal lesion which was not found on subsequent radiological or operative study of the patient. A false negative scan





F g 8 Ante or scan and r ght carotid angiogr m n pat ent w th a hu e chromophobe adenoma invadin the right f ntal lobe

disturbances probably representing the so called Munchausen syndrome Although the scan indicated a parasellar localization of the i otope no organic cause for this has yet been determined The other patient in this group was an elderly man with signs and symptoms of an agitated depression His scan was rather unequivocally positive in the right parasellar region Although there were no definite neurological signs angiography and encephalography were performed both with negative results

Probable false positive scans were considered to be present in 4 patients since no full follow up was available The first of these was an elderly man with diabetic neuropathy and eizures The patient had a moderate degree of hypertension and clinically was suspected of having a possible intracerebral hemorrhage The scan revealed an area of abnormal uptake in the left anterior frontal region No other neurodiagnostic procedures could be performed before the patient expired True correlation was impossible as autopsy was not permitted The second patient in this probably false positive category was a woman with hyperthyroidism and opththalmoplegia of unknown cause The scan suggested an area of increased uptake in the midline temporo occipital region No ancillary tests were performed and the cau e of the opthalmoplegia was never documented The patient is currently being followed in the out patient department The third patient was a woman with a history of migraine headache and numerous psychogenic problems A diagnosis of multiple



Fig. 7. Anterior scan in patient with a subdural hematoma (chronic).

Total number of patients with brain neoplasms scanned	38
Positive scans of patients in tumor group	34
Negative scans of patients in tumor group	
Foramen magnum tumor	4
Multiple small cerebral metastases (pancreas)	
Probable parietal glioma, biopsy specimen revealed gliosis only	
Posterior fossa cholesteatoma	
Per cent positive scans in patients of tumor group	89.4%

Lesions other than neoplasms demonstrated by brain scanning were as follows:

Vascular accidents	5
Skull lesions (1 osteoma, 2 metastases, 1 depressed fracture)	4
Postoperative changes	3
Subdural hematoma	2
Arteriovenous malformations	2
Focal atrophy (confirmed by pneumography)	1
Multiple sclerosis with focal lesion	1
Thalamotomy lesion (electrical)	1
Cranioplasty (tantalum)	1

Representative scans are shown in Figs. 5 through 11.

Review of the false positive and false negative scans revealed two cases where the results were definitely false positive. The first patient was a middle-aged woman with bizarre and diffuse complaints of headache and ataxia with no definite neurological findings. Electroencephalography, roentgenograms of the skull, and further neurological evaluation, revealed no definite objective findings. Subsequent history showed that the patient had severe psychiatric





Fig 8 Anterior scan and right carotid angiogram in patient with a huge chromophobe adenoma invading the right frontal lobe

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Fig 10 Right lateral scan and lateral view of late arterial phase obtained by right carotid angiography in a patient with a small astrocytoma of the right occipital lobe The only symptom was that of seizures

The two probable false negative scans were two cases of astrocytoma removed (presumably subtotally) up to 10 years prior to scanning One was in the left parietal region and the other was in the left temporal region

Discussion

While the apparent diagnostic accuracy of existing methods of brain scanning has not been greatly improved in the present study, the rate at which the scans can be carried out has been greatly increased and the radiation dosage to the patient has been greatly reduced Although this technique is not completely transferable to other scanning systems modification of collimators and scan speed permit a substantial reduction in scanning time In fact it has been possible by a relatively minor modification to increase the scan speed of our Picker Magna Scanner to 420 cm/min We have yet to explore in detail the possible gains obtainable with higher resolution

It should be emphasized that the scan pictures shown here are smoothed primary photographic *records* *without* contrast enhancement or background subtraction It was our thought that the further processing of these film records by closed circuit television or flying spot scanning for contour enhancement contrast enhancement and background subtraction under the control of the observer might lead to greater ease in interpretation That the primary records are so easily interpreted seems remarkable one factor certainly being the very large amount of information recorded in scans consisting of 300 000



Fig 9 Left lateral and anterior scans and axial view of left carotid angiogram in a patient with a left sphenoid wing meningioma

sclerosis made elsewhere was not confirmed at the University of Chicago Clinics Although her scan suggested an area of increased uptake in the midline fronto central region, no neurodiagnostic studies were performed During the three months the patient has been followed as an out patient no clinical evidence of a mass lesion has developed The final patient in this group was a middle aged man with psychosis and dementia thought probably to represent a presenile type of degeneration The patient had no localizing signs on neuro logical examination Evidence for an area of increased uptake in the right parasellar region was seen on the scan The patient refused carotid angio graphy, and is at present lost to follow up

There were 10 cases of false negative scans Of these, eight fell into the definite, and two into the probable, category Of the definite false negatives, three patients gave clinical and radiologic evidence of encephalomalacia in the right cerebral hemisphere, of varying duration, all longer than one year There was one patient with multiple small metastases from a pancreatic carcinoma One patient had a history of trauma and lowering level of con sciousness, the scan revealed no focal uptake, but following a rapid clinical decompensation a large left subdural hematoma was evacuated There was one patient who had on neurodiagnostic evaluation a mass lesion in the left parietal region, but this was not confirmed at biopsy It was felt clinically that the patient probably harbored an astrocytoma diffusum, but histological evi dence was never obtained in a non equivocal manner Of the remaining two patients, one gave evidence of a bilateral cholesteatoma involving both the posterior and middle cranial fossae with a history of previous surgery The remaining patient had, one day prior to the performance of the scan, undergone a thalamotomy for Parkinson s disease The scan failed to reveal evidence of a lesion

Acknowledgements

The authors gratefully acknowledge the essential contributions of Paul Edelberg Charles R Breback Bernard W Frommes John J Stupka and Alexander Smila to the design and painstaking construction of the brain scanner and the care with which the scans were done by Miss Rose Lee Seslar

SUMMARY

A conventional brain scanning system is described in which multiple improvements have resulted in a very substantial increase in performance Preliminary clinical results in 175 patients indicate no appreciable sacrifice in diagnostic accuracy with a considerable reduction in scan time

ZUSAMMENFASSUNG

Konventionelle cerebrale Szintigraphie ist infolge einer vielseitigen Verbesserung nunmehr wesentlich leichter durchzuführen Vorläufige klinische Resultate von 175 Patienten zeigen keine wahrnehmbare Einschränkung der diagnostischen Sicherheit jedoch eine beträchtliche Reduktion der Untersuchungszeit

RÉSUMÉ

Description d un appareil classique de scintigraphie cérébrale dont les performances ont été tres améliorées par de nombreux perfectionnements Les résultats préliminaires sur 175 malades montrent que la précision du diagnostic n a pas été appréciablement diminuée malgré une réduction importante de la durée du balayage

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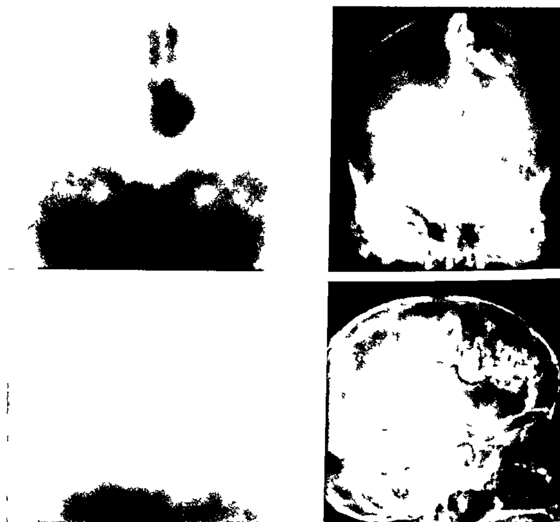


Fig. 11. *Top views*: Frontal scan and carotid angiogram of patient with a large arteriovenous malformation; the scan was performed as an incidental procedure and angiography was performed only after the scan films had been examined. *Lower views*: Lateral scan and angiogram.

to 500 000 counts. This is many times the number of counts usually collected with currently available scanning systems, and approaches the rate of information collection of the camera type detectors (which, incidentally, work very effectively with ^{99}Tc) (ANGER 1964). It would appear that the limitations of conventional scanning systems have not yet been reached. By the use of multiple head detectors moving rapidly it should be possible to approach or equal the sensitivity of a camera detector while maintaining the resolution possible with the focused collimator systems. It may be that some combination of these systems, either separately or in hybrid form, will ultimately prove to be the most satisfactory.

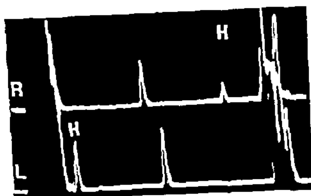


Abb 1 Echoencephalogramm eines 15 jährigen Jungen mit Verdacht auf epidurales Haematom links 21 mm vor dem Endecho kommt bei der Ableitung von rechts (R) ein Haematomecho (H) u Darstellung das an der Grenzflache Gehirn Dura Blutung entsteht Auch von links (L) ist das Haematomecho (H) zu erkennen Außerdem Verschiebung des Mittelechos von links nach rechts um 5 mm Echoencephalographische Diagnose epidurales Haematom links temporal Bestatigung durch Carotisangiographie

weniger Minuten auf Grund der Verschiebung des Mittelechos lokalisieren Ausnahmen bildeten nur die doppelseitigen Haematome Lediglich in 2 Fallen mit multiplen Kontusionen und gleichzeitig bestehenden ausgedehnten Kopfschwartenhaematomen war die Lage des Mittelechos nicht zu beurteilen

Neben der Mittelechoverlagerung konnen in vielen Fallen von der Grenzflache Hirngewebe/Haematom besondere Reflexionen abgeleitet werden die wir als Haematomecho bezeichnen Als erste machten TER BRAAK GRANDIA & DE VLIEGER auf diese Reflexion aufmerksam Einige Autoren haben dagegen das Haematomecho nicht nachweisen konnen (JEPPSON) oder bezweifeln

Tabelle 1

Verhalten des Mittelechos nach Schadel Hirnverletzung (314 Patienten)

Art der Verletzung	Gesamtzahl	Mittelecho normal	Mittelecho verlagert	Mittelecho nicht zu beurteilen
Commotio cerebri	141	141	—	—
Contusio cerebri	9	42	48	2
Extracerebrales Haematom	81	11	70	—

AUS DER NEUROCHIRURGISCHEN KLINIK (DIREKTOR: PROF. W. SCHIEFER) DER UNIVERSITÄT ERLANGEN-NÜRNBERG, DEUTSCHLAND

ECHOENCEPHALOGRAPHISCHE UNTERSUCHUNGS-ERGEBNISSE BEI SCHÄDEL-HIRNVERLETZUNGEN*

von

E. KAZNER und W. SCHIEFER

Unter 1 250 Patienten, die in den letzten Jahren an unserer Klinik mit der temporalen Echoencephalographie nach LEKSELL untersucht wurden, waren mehr als 300 Schädel-Hirnverletzte. Wir verwendeten einen Echo-Encephalographen Typ USM 1 nach KRAUTKRAMER der Firma Siemens-Reiniger AG. Die Echogramme wurden mit einer Polaroid-Land-Camera für die Dokumentation fixiert.

Die speziellen Vorteile der Echo-Methode in der frühen Phase der Schädel-Hirnverletzung sind die Leichtigkeit und Schnelligkeit in der Anwendung. Besondere Aufmerksamkeit widmeten wir der Erkennung posttraumatischer Komplikationen.

Tabelle 1 zeigt das Verhalten des Mittelechos nach Schädel-Hirnverletzungen. Bei einfachen Gehirnerschütterungen fand sich das Mittelecho immer an normaler Stelle. Ein großer Teil der Hirnkontusionen entwickelte in den ersten Tagen nach dem Trauma eine Massenverschiebung mit entsprechender Mittelechoverlagerung, maximal bis zu 5 mm. Der echoencephalographisch nachweisbare, spätere Rückgang dieser Verlagerung bestätigte die Diagnose einer Kontusion. Alle Blutungen im Bereich einer Hemisphäre ließen sich innerhalb

* Herrn Prof. Max Schneider zum 60. Geburtstag gewidmet.

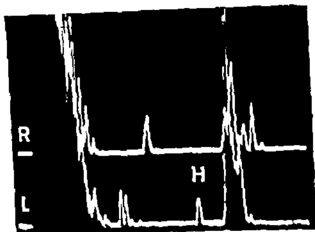


Abb. 3. Echogramm einer 16jährigen Patientin mit Verdacht auf raumfordernde intrakranielle Blutung. Mittelecho-Verschiebung von rechts nach links um 7,5 mm. Man erkennt zusätzlich bei der Ableitung von links mit nach temporo-praezentral gerichtetem Ultraschallstrahlenbündel 18 mm vor dem Endecho eine Reflexion H. Echoencephalographische Diagnose: epidurales Haematom rechts temporo-praezentral.

und die Aufnahme mit um 30 Grad nach links gedrehtem Kopf bestätigte die echoencephalographische Diagnose. Bei der Operation wurde das atypisch lokalisierte, weit nach occipital reichende Haematom erfolgreich ausgeräumt.

Anfangs haben wir nach der Echoencephalographie zur Sicherheit immer noch angiographiert. In Notsituationen läßt sich aber, wie der nächste Fall zeigt, hierauf verzichten. Abbildung 3 zeigt das Echobild eines 16jährigen Mädchens, das 12 Stunden nach einem Motorradunfall mit sekundärer Bewußtlosigkeit und Streckkrämpfen aufgenommen wurde. Die Erweiterung der linken Pupille schien für eine linksseitige Blutung zu sprechen. Das Echogramm wies aber eine deutliche Mittelechoverschiebung nach links auf und bei Ableitung von links mit nach temporo-praezentral gerichtetem Ultraschallstrahlenbündel tauchte eine Reflexion (H) auf, sodaß wir ein in dieser Region gelegenes epidurales Haematom vermuteten (Abb. 3). Ohne weitere Diagnostik erfolgte die operative Ausräumung der Blutung. Der erhebliche Zeitgewinn hat hier sicher zu dem günstigen Ausgang beigetragen.

Insgesamt konnten wir 28 epidurale Haematome mit Ultraschall untersuchen. Bei allen temporalen, temporo-parietalen, temporo-occipitalen und temporo-praezentralen Blutungen fand sich neben der Massenverschiebung das erwähnte Haematomecho. Nur die frontalen, temporo-basalen und occipitalen Haematome, die bei der üblichen Untersuchungstechnik nicht direkt

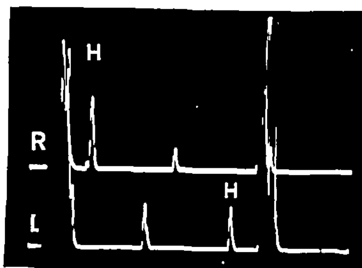


Abb. 2. Echoencephalographische Diagnose eines epiduralen Haematoms rechts temporo-occipital bei einem 8jährigen Jungen mit klinischer Beschwerdefreiheit. Man erkennt das Haematomecho H, das von beiden Seiten her ableitbar ist. Daneben Verlagerung des M-Echos von rechts nach links

dessen Signifikanz (LITHANDER). Unsere Untersuchungsergebnisse, die im folgenden durch einige Fallberichte erläutert werden, lassen jedoch kaum Zweifel an der Existenz derartiger Reflexionen zu.

Bei einem typischen *Epiduralhaematom* auf der linken Seite zeigt sich im Echoencephalogramm bei der Beschallung von rechts (R) eine Verlagerung des Mittelechos zur gleichen Seite und zusätzlich eine Reflexion (H), die dem Endecho vorauseilt. Bei Beschallung von links (L) wird dieses Echo (H) sofort nach dem Initialecho sichtbar (Abb. 1). Der Abstand zwischen diesem Haematomecho und dem Endecho entspricht der angiographisch und bei der Operation festgestellten Ausdehnung der Blutung. Zweifellos handelt es sich bei dem sogenannten Haematomecho um eine an der Grenze zwischen Gehirnoberfläche, Dura und Blutung entstandene Reflexion.

Der nächste Fall läßt den Wert der Echo-Methode noch eindeutiger erkennen. Ein 8jähriger Junge wurde 2 Tage nach einem Schädeltrauma zu uns eingewiesen. Bei der Aufnahme war er wach, der neurologische Befund bis auf ein Spreizphänomen am rechten Fuß normal. Nach dem EEG wurde eine Kontusion im rechten Schläfenlappen angenommen. Im Echoencephalogramm fanden wir aber eine Verlagerung des Mittelechos von rechts nach links um 8 mm und eine von beiden Seiten ableitbare Reflexion (H), sodaß wir ein epidurales Haematom rechts temporooccipital diagnostizierten (Abb. 2). Im a.-p. Phlebogramm sah man eine Verlagerung der Vena cerebri interna nach links

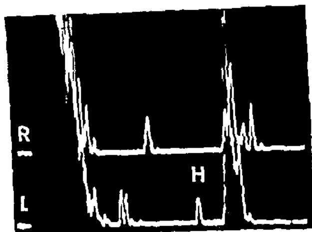


Abb 3 Echogramm einer 16-jährigen Patientin mit Verdacht auf raumfordernde intrakranielle Blutung Mittelechoverschiebung von rechts nach links um 7 5 mm Man erkennt zusätzlich bei der Ableitung von links mit nach temporo-praezentral gerichtetem Ultraschallstrahlenbündel 18 mm vor dem Endecho eine Reflexion H Echoencephalographische Diagnose epidurales Haematom rechts temporo-praezentral

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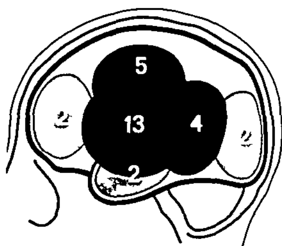
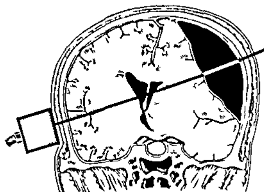


Abb. 4. Echoencephalographische Befunde bei 28 epiduralen Haematomen. Alle temporalen, temporo-occipitalen, temporo-parietalen und temporo-praezentralen Blutungen riefen eine Mittelechoverlagerung und ein Haematomecho hervor (dunkelgrau). Nur die frontalen, temporo-basalen und occipitalen Haematome zeigten eine Mittelechoverlagerung ohne Haematomecho, da diese Blutungen nicht direkt vom Ultraschallstrahl erfaßt werden (hellgrau)

vom Ultraschall erfaßt werden, zeigten kein Haematomecho. Die richtige Seitenlokalisation ergab sich aber auch hier durch die Mittelechoverlagerung (vgl. Schaubild in Abb. 4).

Das klinische Bild des epiduralen Haematoms hat manche Ähnlichkeit mit dem des *akuten subduralen Haematoms*. Hier können oft die echoencephalographischen Befunde zur Differentialdiagnose beitragen: beim akuten subduralen Haematom gelingt es nämlich gelegentlich zwar auch eine Reflexion von der Blutansammlung zu erhalten. Diese ist aber nach unseren Beobachtungen nie so signifikant wie beim Epiduralhaematom.



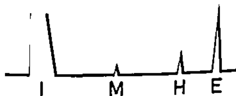


Abb. 5. Schematische Darstellung der Schrägbeschallungstechnik beim chronischen subduralen Haematom. Bei weitgehend senkrechtem Auftreffen des Ultraschalls auf die Haematomoberfläche erhält man eine deutliche Reflexion von dieser Grenzfläche (H). Das Mittelecho (M) hat bei dieser Technik eine sehr geringe Amplitude oder verschwindet ganz.

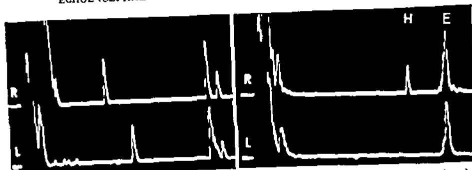


Abb. 6. *Links*: 11 mm von links nach rechts verlagertes Mittelecho spricht für raumfordernden Prozeß links. *Rechts*: bei der Schrägbeschallung Reflexion (H) 25 mm vor dem Endecho bei rechts (R) aufgesetztem Prüfkopf. Echoencephalographische Diagnose: chronisches subdurales Haematom links mit 25 mm Durchmesser

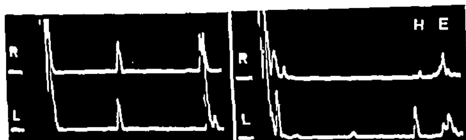


Abb. 7. Doppelseitiges chronisches subdurales Haematom. *Links*: Mittelecho im Bereich der Norm. *Rechts*: Ergebnis der Schrägbeschallung: Haematoreflexionen (H) beiderseits vor dem Endecho

Zur Erkennung des *chronischen subduralen Haematoms* hat sich uns (SCHIEFER, KAZNER & BRUCKNER 1963) eine besondere Beschallungstechnik bewährt (siehe schematische Darstellung in Abb. 5). Bei der üblichen horizontalen Beschallung läßt sich bei einseitigen Haematomen zwar die Mittelechoverlagerung feststellen. Das meist parietal gelegene Haematom wird aber nur erfaßt, wenn das Ultraschallstrahlenbündel die Grenzfläche zwischen Hirngewebe und Blutung weitgehend senkrecht trifft. Deshalb richten wir bei Verdacht auf eine derartige Erkrankung den Ultraschall schräg nach oben. Bei Vorliegen eines subduralen Haematoms wird dann auf dem Bildschirm ein charakteristisches Haematomecho (H) sichtbar.

Abbildung 6 zeigt einen solchen Fall: Ein 41 jähriger Mann wurde bei uns 8 Wochen nach einem Schädel-Hirntrauma mit Verdacht auf subdurales Haematom aufgenommen. Das Echogramm wies eine 11 mm Massenverschiebung von links nach rechts auf. Bei der Schrägbeschallung wurde von rechts her eine Reflexion (H) sichtbar, die ein 25 mm dickes Haematom anzeigte.

Tabelle 2

Echoencephalographische Befunde bei 81 extracerebralen Blutungen

	M-Echo normal	M Echo shifted	Hematoma Echo	Midline-Displacement (mm)
extradural Hematoma 28	–	28	22	7,4
acute subdural Hematoma 23	–	23	9	7,3
chron subdural Hematoma 16	–	16	15	8,2
chron subdural Hematoma doublesided 14	11	3	10	
	11	70	56	

Die Diagnose wurde durch Angiographie und anschließende Operation bestätigt.

Auch doppelseitige chronische Subduralhaematome, die ja meist keine Verschiebung des Mittelechos hervorrufen, können durch die Schrägbeschallung oft dennoch nachgewiesen werden. Sowohl von links als auch von rechts erhält man Haematomechos (H), die dem Endecho (E) vorauseilen und die Haematomdicke erkennen lassen (Abb. 7).

JEPPSON glaubt, daß es sich bei den Haematomechos um Reflexionen von Knochenvorsprüngen an der Innenseite der Schädelkalotte handeln könne. Dieser Einwand läßt sich durch den nächsten Fall einfach entkräften. In Abbildung 8 sind die Echogramme eines 59jährigen Mannes mit einem chronischen subduralen Haematom über der linken Hemisphäre zusammengestellt. Vor der Operation zeigte sich ein Haematomecho (H) 25 mm vor dem Endecho (E). Die bei der Operation gemessene Dicke der Blutung betrug 2,5 cm. 8 Tage später ließ sich durch die Reflexion H noch ein Resthaematom von 12 mm Durchmesser nachweisen. Daraufhin wurde am folgenden Tage nachpunktiert und gleichzeitig der Liquorraum von lumbal her mit phys. Kochsalzlösung aufgefüllt. Im Echoencephalogramm war während dieser



Abb 8 Ch oni ches subdurales Haema tom l nks be e nem 59 jahr gen Mann Von oben nach unten (alle Echogramme nd m t de Schragbeschallungstechn k er elt Untersuchung vor der Opera t on H ematomecho H in 25 mm Abtand om Endecho E 8 Tage p op liegt noch ein 1? mm d ckes Resthaematom or angeze gt dur h das Haematomecho H Am folgende Tage Asp rat on des Resthaemat m Dabei wandert das Haem tomecho H in R chtung auf da Endecho B e ne mbul nten Kon tr lle r Wochen sp ter ist kein Hae mat n e ho m hr nachwe b r

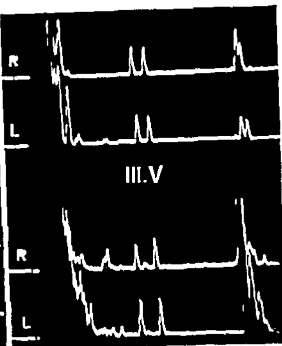


Abb 9 22 jahrige Patient mit schweren gedecktem Schadel Hirntrauma *Oben* Echogramm 24 Tage nach der Verletzung Es zeigt eine beginnende Ventrikeler weiterung n Das gedoppelte M ttelecho (III V) entst ht an den Seitenwanden des 3 Ventr kels dessen Weite sich sofort ablesen laßt Unten we t re 18 Tage spater hat der Abstand der be den vom 3 Ventrikel stammenden Reflex onen deutlich zugenommen D ag nose erhebl cher posttrau nat sche Hydrocephalus in ternus

Manipulation ein Wandern des Haematomechos (H) auf das Endecho zu zu beobachten (3 Kurve von oben) Bei einer ambulanten Kontrolluntersuchung 1 Monat spater fehlte diese zusatzliche Echo In solchen Fallen kann zumindest auf die Kontrollangiographie nach Entleerung eines subduralen Haematoms verzichtet werden

Tabelle 2 faßt unsere echoencephalographischen Befunde bei insgesamt 81 extracerebralen Haematomen zusammen Alle 67 einseitigen Blutungen wurden mit Hilfe des Echo-Impuls Verfahrens richtig seitenlokalisiert Die durchschnitt

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konnte eine zusatzliche Reflexion das sogenannte Haematomecho aufgefangen werden Dies ermoglichte oft die genaue Diagnose Auch die meisten chronischen subduralen Haematome wurden bei Anwendung einer besonderen Beschallungstechnik durch ein Haematomecho erkannt

SUMMARY

Echo-encephalography has become indispensable for th quick recognition of complications in cerebral trauma on account of its great speed its reliability and the facility of repeated control examinations In all 314 cases of skull injury were investigated Some cases of contusion but all those of unilateral haematomas produced a displaced midlin echo An additional reflection was registered the so-called haematoma echo wherever an epidural haematoma was sounded vertically by ultrasonic waves This phenomenon frequently permits accurate diagnosis Equally most of the chronic subdural haematomas were recognisable by means of a special ultrasonic technique

RÉSUMÉ

En raison de sa rapidité de sa fidélite et de la possibilite de la répéter l écho encéphalographie est devenue indispensable pour faire en temps utile le diagnostic des complications des traumatismes cranio-cérébraux Les auteurs ont examiné 314 traumatisés craniens Ils ont trouvé un déplacement de l écho médian dans une partie des contusions et dans tous les hématomes unilatéraux Dans tous les cas ou les ultra sons abordent l hématome extra dural perpendiculairement sur une grande surface on a constaté une réflexion supplémentaire appelée l écho d hématome Ceci permet souvent le diagnostic exact La plupart des hématomes sous duraux chroniques ont aussi pu être identifiés par un echo d hématome grace a une technique spéciale

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liche Massenverschiebung im Echogramm betrug 7—8 mm, ein signifikanter Unterschied zwischen den einzelnen Blutungsformen war dabei nicht erkennbar. Bei 3 doppelseitigen chronischen Subduralhaematomen fand sich eine geringe Mittelechoverlagerung, bedingt durch die unterschiedliche Größe der Blutungen. Die übrigen zeigten ein normales Mittelecho.

Bei den 81 extracerebralen Haematomen konnten wir 56 mal Reflexionen von der Blutung, sogenannte Haematomechos registrieren. Von 23 akuten subduralen Blutungen wiesen nur 9 eine solche Reflexion auf, dagegen von 28 Epiduralhaematomen 22. Bei 30 chronischen Subduralblutungen fanden wir ein Haematomecho sogar in 25 Fällen, bei den einseitigen Haematomen fast immer. Wir halten das Haematomecho bei den epiduralen und chronischen subduralen Blutergussen fur ein sehr zuverlässiges diagnostisches Hilfsmittel.

Neben den posttraumatischen intrakraniellen Blutungen sind es vor allem die Folgezustände schwerer gedeckter Schädel-Hirnverletzungen, bei denen die Echoencephalographie wertvolle Befunde liefert. Genauso, wie wir bei den infratentoriellen Prozessen schon vor der Luftfullung echoencephalographisch die Weite der 3. Hirnkammer bestimmen konnen, ist dies auch bei hirnatrophischen Vorgängen nach Hirnverletzungen moglich. Von einem Ansatzpunkt direkt uber der Ohrmuschel beschallt man den 3. Ventrikel und erhält von dessen seitlichen Wänden getrennte Reflexionen, deren Abstand uns die Weite der 3. Hirnkammer angibt. Abbildung 9 demonstriert einen solchen Fall. Man erkennt im Echoencephalogramm deutlich den großer werdenden Abstand der beiden vom 3. Ventrikel stammenden Echos. Die Diagnose eines zunehmenden Hydrocephalus internus kann damit ohne eingreifendere Untersuchungen sicher gestellt werden.

Wenn auch die echoencephalographischen Befunde nur im Rahmen der gesamten klinischen Symptomatologie bewertet werden dürfen, so hat diese Methode inzwischen doch zunehmende Bedeutung in der neurologischen Diagnostik gewonnen. Sie ist gerade fur die rechtzeitige Erkennung der Fruh- und Spatkomplikationen nach Schädel-Hirnverletzungen wegen der Schnelligkeit in der Anwendung, der beliebigen Wiederholbarkeit und ihrer Zuverlässigkeit unentbehrlich geworden.

ZUSAMMENFASSUNG

Fur die rechtzeitige Erkennung von Komplikationen nach Schadel-Hirnverletzungen ist die Echoencephalographie wegen ihrer Schnelligkeit, beliebigen Wiederholbarkeit und Zuverlässigkeit unentbehrlich geworden. Es wurden 314 Schadelverletzte untersucht. Bei einem Teil der Kontusionen und allen einseitigen Blutungen fand sich eine Verlagerung des Mittelechos. Bei allen vom Ultraschall weitgehend senkrecht getroffenen epiduralen Haematomen

FROM THE DEPARTMENTS OF RADIOLOGY AND NEUROSURGERY OF THE HOSPITAL OF THE UNIVERSITY OF PENNSYLVANIA AND THE DEPARTMENT OF NEUROLOGY OF THE CHILDREN'S HOSPITAL, PHILADELPHIA, PENN., U.S.A.

BRAIN SCANNING OF CHILDREN USING BODY SECTION TECHNIQUES AND PERTECHNETATE ^{99} Tc

by

D. E. KUHL, F. W. PITTS and S. H. TUCKER

Radionuclide scanning is now widely accepted as an effective, yet relatively atraumatic, method for studying the adult brain. In spite of this, experience in brain scanning of children is limited.

This is a report of our 6 months experience (1964) in rapid brain scanning of children using pertechnetate ^{99m}Tc and tomographic separation of the brain images. We chose the scanning agent pertechnetate ^{99} Tc to keep radiation exposure of the child low, even when we gave large doses of radionuclide to increase the count rate. With high count rate, fine resolution collimation could be used, the scan speed was increased, and multiple high quality images were obtained in an acceptable period of time. Tomographic scanning was used to demonstrate the radioactive brain in cross section. We explored the use of transverse section scanning in order to improve the description of lesion extent in three dimensions. We predicted that this body section scanning technique should increase the accuracy of detecting lesions of the base of the brain and in the posterior fossa by reducing the obscuring effect of the images of overlying radioactive muscle and blood pools.

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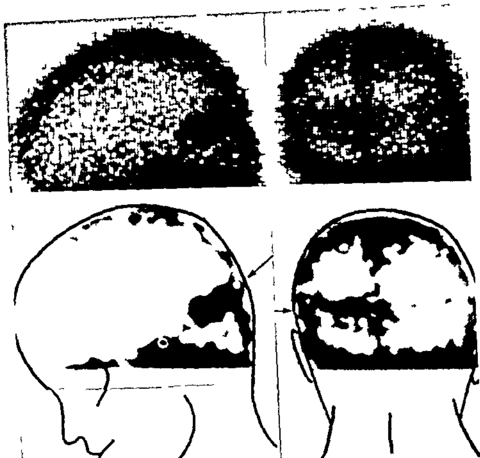


Fig 1 Left cerebellar astrocytoma of 13 year-old child rectilinear scanning The top views were generated from data on paper tape as matrices of elements each representing a measurement of 0 25 cm × 0 25 cm over the patient The lower views are the same scans modified with contrast enhancement and a glass diffusion filter

For ordinary rectilinear scanning two opposed scintillation detectors scan both sides of the head simultaneously Each detector has a sodium iodide crystal 2 inches thick and 3 inches in diameter The collimators used for rectilinear scanning are designed for lower energy photons and have a 1/2 inch diameter of view at the focal length of 3 inches (KUHL in press) Pulse height analysis is used to count photons in a 50 keV window centered on the 140 keV photopeak Count rates over the head vary from 100 to 500 counts per second The scan speed is 2 cm/sec and the line spacing is 0 25 cm

At the time of scanning two channels of counting and positional data

Radioactive agent. The brain scanning agent most widely used in the United States at present is chlormerodrin ^{203}Hg, introduced by BLAU & BENDER (1960, 1962). The radioactive label ^{203}Hg has a 279 keV photon emission, an average beta energy of 0.10 meV, and a 47.9 day physical half life. Unfortunately, the compound has the undesirable property of concentrating in the renal cortex. GREENLAW & QUAIFE (1962) estimated that 75 % of the administered dose leaves the body with a biologic half life of 5 hours, while the remaining 25 % remains in the kidneys, disappearing with a biologic half life of 8.2 days. In the absence of an effective blocking agent to abolish renal concentration, the usual dose of 10 microcuries per kg body weight delivers a radiation dose of 25 to 30 rad to the kidneys of a child.

Because of this kidney dose chlormerodrin labeled with the shorter lived ^{197}Hg was considered for use in children. ^{197}Hg has a 77 keV photon emission, an average 'beta' energy of 0.077 MeV, and a physical half life of only 2.7 days. Earlier reports by SODEE (1963, 1964), FEINDEL et coll. (1964), and RHOTON et coll. (1964) estimated that equal microcuries of chlormerodrin ^{197}Hg should deliver only 1 % to 10 % of the renal radiation dose of chlormerodrin ^{203}Hg. Using the more recent nuclear spectral data of HARRIS & ROHRER (1964), we estimate that the ^{197}Hg label reduces the renal dose to about 20 % of that expected with the ^{203}Hg label, on an equal microcurie basis. This is still a significant advantage in favor of chlormerodrin ^{197}Hg, but it is an advantage that cannot be fully realized, due to scatter problems associated with counting the 77 keV photon emission (HARRIS et coll. 1963, ROSS et coll. 1964).

The brain scanning agent pertechnetate ^{99}Tc, introduced by HARPER et coll. (1964), has properties particularly advantageous for use in children. The compound is easily recovered each day from a molybdenum ^{99}Mo generator (STANG & RICHARDS 1964). It has a 140 keV photon emission, an average 'beta' energy of only 0.014 MeV, and a physical half life of only 6 hours. The photon energy is very near the optimum for brain scanning predicted by BECK (1961). There is no preferential concentration in the kidneys. The small concentration in the thyroid gland is prevented by iodide premedication. Because of the low energy dissipation in tissue and the short half life, the radiation exposure to the patient is very low, even when the radionuclide is used in large amounts. At present we administer 200 microcuries per kg body weight for high count rate brain scanning of either children or adults. The total body radiation dose is approximately 120 millirad.

Instrumentation and technique. The theory and operation of the scanning system used in this study has been described in detail elsewhere (KUHL 1963, 1964).

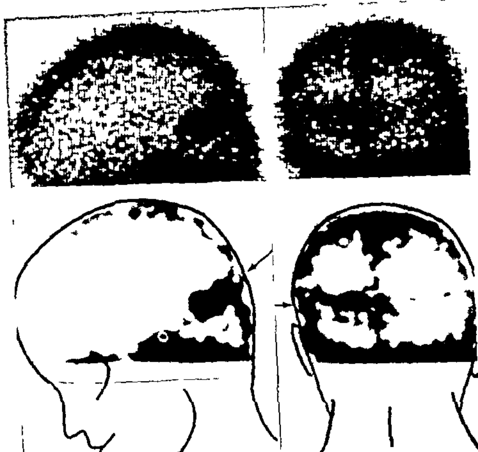


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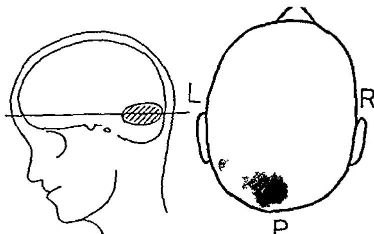


Fig 3 Transverse section scanning of left cerebellar astrocytoma which is the same tumor as shown in fig 1 Section image of the transverse venous sinus is seen on either side of the tumor Scanning time 10 min

very restless child we give 1 to 4 ml of paraldehyde intramuscularly, deep in the buttocks immediately before scanning

Brain scanning is begun 15 minutes after injection of the radionuclide This early time of scanning is convenient when a large number of patients are to be studied Also it is our impression that detection effectiveness is more favorably influenced by the high early count rate than by improving the tumor to blood radionuclide concentration ratio by later scanning

The routine examination is a four view, rectilinear survey (anterior posterior right lateral and left lateral) and a transverse section scan through the base of the brain If localizing signs are prominent the section level is chosen through the region of particular interest The total scanning time for each patient is one hour

Results

Diagnostic accuracy In the past six months (1964) we have studied 38 children of less than 13 years of age with pertechnetate ^{99m}Tc and this scanning system The report of each examination included a narrative interpretation and a classification of the results as definitely abnormal probably abnormal probably normal or definitely normal

Among the children in the total group 20 had a final diagnosis of a brain lesion established by consideration of clinical findings electroencephalography neuroradiography surgical exploration or autopsy as shown below

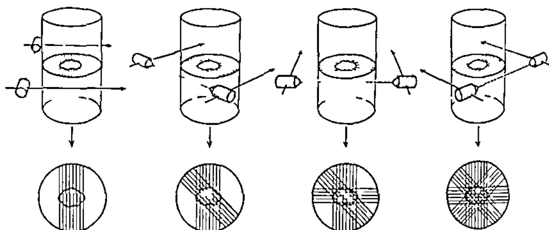


Fig 2 Transverse section scanning A pair of detectors scan the circumference of the head from many different directions The resulting record displays the radioactivity in a thin cross section of brain

are alternately recorded in binary code on perforated paper tape at spacial sampling intervals of 0 25 cm Later, the tapes are read at 300 characters per second to control the raster and the beam brightness of an oscilloscope so as to generate the pictures rapidly on Polaroid film During this playback processing, the contrast is under the control of the operator Each paper tape is stored as a permanent record for possible future reference to the undistorted data In some instances, interpretation has been facilitated by the additional use of glass diffusion filters and closed circuit television for viewing the polaroid pictures (Fig 1)

For section scanning, an entirely different scanning pattern is required (Fig 2) The transverse section scan is analogous to the axial transverse tomograph and represents the radioactivity in a cross section of the brain approximately 1 or 2 cm thick The collimators used for section scanning are also of lower energy design, but have a diameter of view of 1/2 inch at a more distant focal length of 4 5 inches The pair of detectors makes a sequence of tangential scans at angular intervals of 7 5 degrees around the complete circumference of the patient s head, at the level of the cross section desired The scan speed is 2 cm/sec When the picture is generated from the data on the paper tape bands of increased film exposure, corresponding to radioactivity converge and overlap on the film to represent the image of radioactive structures in the transverse section (Fig 3) One complete transverse section image requires approximately 10 minutes of scanning time

During the study, soft music is played on a radio and the room is darkened to encourage sleep Sedation is seldom required for child cooperation With a

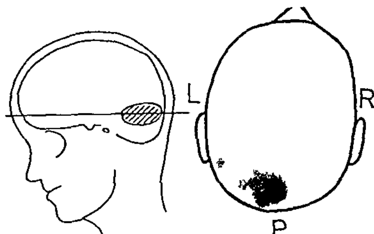


Fig 3 Transverse section scanning of left cerebellar astrocytoma which is the same tumor as shown in fig 1 Section image of the transverse venous sinus is seen on either side of the tumor Scanning time 10 min

very restless child we give 1 to 4 ml of paraldehyde intramuscularly deep in the buttocks immediately before scanning

Brain scanning is begun 15 minutes after injection of the radionuclide This early time of scanning is convenient when a large number of patients are to be studied Also it is our impression that detection effectiveness is more favorably influenced by the high early count rate than by improving the tumor to blood radionuclide concentration ratio by later scanning

The routine examination is a four view rectilinear survey (anterior posterior right lateral and left lateral) and a transverse section scan through the base of the brain If localizing signs are prominent the section level is chosen through the region of particular interest The total scanning time for each patient is one hour

Results

Diagnostic accuracy In the past six months (1964) we have studied 38 children of less than 13 years of age with pertechnetate ^{99m}Tc and this scanning system The report of each examination included a narrative interpretation and a classification of the results as definitely abnormal probably abnormal probably normal or definitely normal

Among the children in the total group 20 had a final diagnosis of a brain lesion established by consideration of clinical findings electroencephalography neuroradiography surgical exploration or autopsy, as shown below

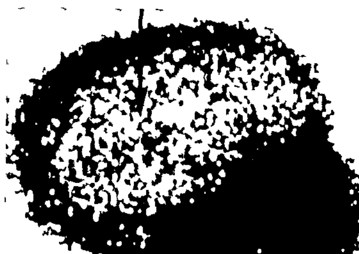


Fig 4 Detectable concentration of pertechnetate in straight sinus and deeper vasculature (arrow) of a three year old child this should not be misinterpreted as abnormal

	Lesion	Location	Number of cases
Tumor (total 12)	Astrocytoma	Optic chiasmal	2
		Hypothalamic	2
		Thalamic	1
		Cerebellar	1
		Pontine	1
	Craniopharyngioma	Hypothalamic	2
	Ependymoma	Temporal	1
	Pinealoma (scanned during a course of radiotherapy to tumor)	Pineal	1
	Sarcoma	Temporal	1
Non tumor (total 8)	Subdural hematoma	Frontal	1
	Intracerebral hematoma	Frontal	1
	Focal inflammation	Temporal	2
		Cerebellar	1
	Abscess	Frontal	1
	Angiomatosis	Hemispheric	2

The interpretations of the scan results of all 20 correctly localized the lesions Of these, 18 had been classified as definitely abnormal and 2 probably abnormal

Of the children in the total group 12 were finally considered to have no tumour or vascular brain lesion on the basis of examinations other than the scanning The scan results of 10 of these children had been interpreted as

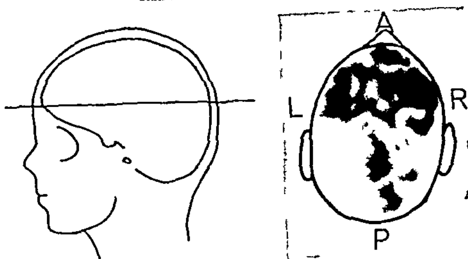


Fig 5 Angiomatosis (Sturge Weber) of right hemisphere and left frontal lobe of an 11 month old child in transverse section

normal (7 definitely normal 3 probably normal) Scan results were interpreted as abnormal in 2 children who are now presumed to have no brain lesion (one definitely abnormal one probably abnormal) These false positive studies were done early in the series In each we misinterpreted the image of normal deep vascularity frequently demonstrated with this scanning technique (Fig 4)

Six children in the total group remain incompletely diagnosed the scan results of three were classified as definitely abnormal two probably abnormal and one probably normal

Section scan results A transverse section scan was included in the examination of 18 of the 20 children subsequently diagnosed as having brain lesions The section records of 15 of the 18 cases demonstrated the lesion

In these 15 cases, the combination of section and rectilinear records provided an unusually complete description of lesion extent Sometimes the lesion topography of a single section record was information unavailable by any other current study method (Fig 5) The improved tumour topography was o particular value to us for neurosurgical planning and design of portals for radiotherapy

The section scan was the only good evidence of localization in the examinations of three children one with an optic glioma and two with focal inflammation in the temporal lobe In each of these cases the image of diseased brain

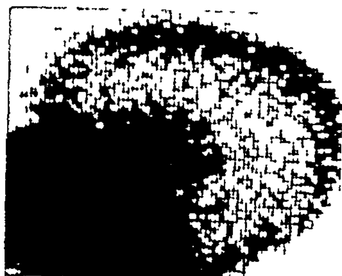
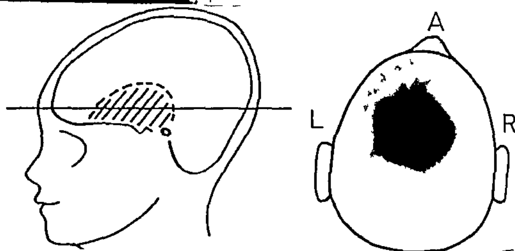


Fig 6 Large glioma arising from optic chiasm of 4 year old child The lateral rectilinear scan (upper left) demonstrates the tumor which is large and extends above the temporal muscle The transverse section image of the tumor is shown below

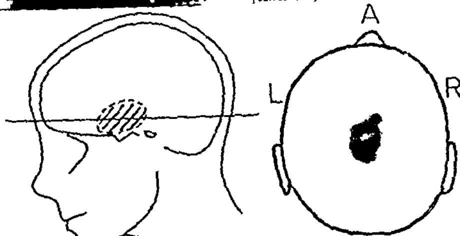


was obscured in the rectilinear scan by images of overlying temporal or occipital muscles With rectilinear scanning a lesion arising low in the brain can be detected effectively above, or even through, these muscles, if the lesion is large (Fig 6), situated laterally, or very radioactive On the other hand, a small midline lesion in this region can be missed (Fig 7) This interference is reduced with the transverse section method, since the lesion image can be demonstrated separate from that of the surrounding wall of muscle (Fig 7)

The section recordings failed to demonstrate a frontal subdural hematoma, a craniopharyngioma, and a pinealoma, all of which were correctly localized on the rectilinear scans The section level was incorrectly chosen for detection of the craniopharyngioma We could not distinguish the transverse section image of the pinealoma from the expected normal image of the straight sinus and other adjacent deep vasculature



Fig 7 Small glioma arising from optic chiasm of 18 month-old child The tumor cannot be distinguished from overlying temporal muscle in the lateral rectilinear scan (upper left) The tumor is demonstrated in the transverse section scan (below) which separates its image from the surrounding muscle image



Section studies were done also on 8 of the 12 children subsequently considered to have no brain lesions All but one of these section examinations were reported as normal The incorrectly diagnosed study was done early in the series and accounted for one of the two false positive results reported above The section image of the deep vasculature was misinterpreted

Discussion

From this 6 month experience (1964) we conclude that pertechnetate ^{99m}Tc is the current agent of choice for brain scanning of children This is because the radiation dose to the child is low yet there is a potentiality for producing multiple high quality images in a short period of time using high count rate fast scanning

Since the radiation dose is low, we have been encouraged to introduce serial scanning at 6 month intervals for follow up examination of patients who have received radiotherapy to the brain Also, we now rescan at shorter intervals to follow the response of inflammatory brain disease to antibiotic treatment

With our present method, diagnostic accuracy is good It is apparent, however, that images of vascular anatomy are demonstrated that we are not accustomed to evaluating With increasing experience in interpreting these images, their delineation eventually may prove to be of diagnostic advantage rather than liability

Our recent experience indicates that transverse section scanning does add additional valuable information about the anatomic distribution of most intracranial lesions When the lesion is so situated that its image is easily confused with overlying muscle, the transverse section scan may be crucial for diagnosis Because of this, we expect that body section scanning technique should increase the accuracy of detecting lesions of the posterior fossa, a region of predilection in children We have yet to demonstrate this advantage, however, since there was a fortuitous scarcity of posterior fossa lesions in our material

The introduction of pertechnetate ^{99} Tc for brain scanning has implications that will influence instrument design For example, the complexity of our present *research scanning system* could be reduced considerably by adapting its design to a very light weight detector system The lower energy photon of ^{99m}Tc (140 keV) requires much less heavy shielding than higher energy emitters more commonly in use at present

Advances in instrument design should also influence the useful application of section scanning With the introduction of even more efficient detecting devices, it may be possible to perform routine multiple layer transverse section scanning at narrow separation intervals as the principal scanning examination If so, we would approach for the first time a true three dimensional representation of brain disease

Acknowledgements

The authors thank Miss Sandra Betz R N and Mrs Martha Guba R N who performed the scanning studies reported in this paper This investigation was supported by U S Public Health Service Research Grant No C 4456 *from the National Cancer Institute* U S Atomic Energy Commission Contract No AT(30 1) 3173 and U S Public Health Service Research Career Program Award CA 14 020 from the National Cancer Institute

SUMMARY

High count rate brain scanning was performed on 38 children using short lived pertechnetate ^{99m}Tc to minimize radiation dose. Four rectilinear views and a transverse section scan were performed during one hour. The section scans improved the outlining of lesion extent and aided detection of brain disease otherwise hidden by radioactive muscle. All 20 confirmed brain lesions (12 tumor, 8 benign) were correctly localized. Two false positives resulted from misinterpreting normal vasculature.

ZUSAMMENFASSUNG

Um die Strahlendosis zu verringern, wurde bei 34 Kindern scanning des Gehirns mit hoher Zahlgeschwindigkeit unter Verwendung von kurzstrahlendem Pertechnate ^{99m}Tc durchgeführt. Vier geradlinige Ansichten und ein Querschnitts scan werden während einer Stunde angefertigt. Das Schnitt scan verbesserte die Möglichkeit der Abgrenzung von ausgedehnten Veränderungen und erleichtert die Aufdeckung einer Gehirnerkrankung, die ansonsten von radioaktiver Muskulatur überlagert wird. Alle 20 nachgewiesenen Gehirnveränderungen (12 Tumore, 8 benign) wurden korrekt lokalisiert. Zwei fälschlicherweise als positiv gedeutete Befunde beruhten auf Fehlbeurteilung normaler Gefässysteme.

RÉSUMÉ

Les auteurs ont fait chez 34 enfants des scintigraphies cérébrales avec un taux de comptage élevé en utilisant un pertechnetate ^{99m}Tc de courte période pour diminuer la dose de radiation. En une heure on fait quatre scintigrammes perpendiculaires et une coupe transversale. Les scintigrammes en coupe améliorent la délimitation de la tumeur et ont facilité la détection d'affections cérébrales qui dans d'autres conditions techniques sont cachées par la radioactivité des muscles. Les 20 lésions cérébrales confirmées (12 tumeurs, 8 bénignes) avaient été correctement localisées. Deux cas faussement positifs étaient dus à une mauvaise interprétation de vaisseaux normaux.

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FROM THE DIVISION OF APPLIED PHYSICS AND RADIO AND ELECTRICAL ENGINEERING
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NOVEL IMMERSION SCANNER AND DISPLAY SYSTEM FOR ULTRASONIC BRAIN TOMOGRAPHY

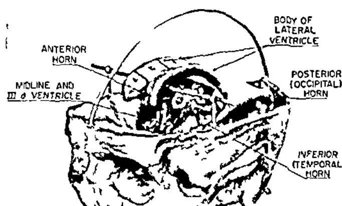
by

D M MAKOW W WYSLOUZIL D N WHITE and J BLANCHARD

At the present time the one dimensional ultrasonic pulse position or A display method to detect midline displacements is gaining ground among neuroradiologists and neurosurgeons To date only the midline echo can be shown reliably and this only when the operator has considerable skill and knowledge

A complete two dimensional horizontal or coronal cross section of the head promises to give a greater amount and more reliable information about the position of the ventricular structures in the brain as can be seen from the bronze model of the skull shown in Fig 1 To obtain a cross section a compound scanning technique is used combining reversible scanning and circular movement around the head Two different methods may be considered in the development of a compound scanner for echoencephalography — the contact or the immersion method

A contact scanner (DE VLIEGER et coll 1963 GREATOREX & IRELAND 1964) has the advantage of small size and mobility as it can be moved to the patient However maintenance of a satisfactory and continuous transducer contact with the skull is difficult and so is the reproducibility of the transducer position with respect to the skull



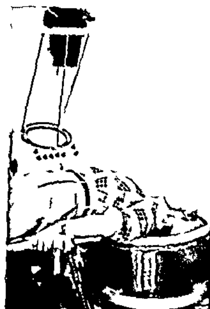


Fig 1 (above) Bronze model of ventricles showing their relative position in the head

Fig 2 (right) Photograph of equipment used in the investigation

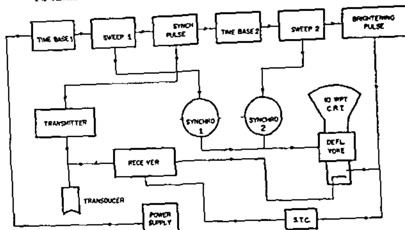
In the immersion scanner, water used as the coupling medium provides satisfactory contact at all times The relative position of the head and transducer can be fixed, thus freeing the operator from the patient Mobility however is limited and in some cases the patient will find it difficult to dip his head in water

About two years ago, we decided to explore the immersion technique first and to develop a suitable display system The results obtained to date are summarized in this paper

Description of apparatus

Fig 2 shows a water tank and the display system The water tank rotates while the transducer is scanning back and forth The combined movement provides a compound scanning motion of the head The patient is lying on his back on a stretcher above the tank with his head bent downwards and immersed in water

An electronic system has been developed which permits a 360 display of echoes from tissue interfaces on the face of a cathode ray tube, shown in Fig 2 These echoes appear in positions which correspond to the location of the reflecting tissues in the brain The source of radiation, the transducer moves on the circumference of a circle with the target in its center This is unlike radar PPI displays, also used in diagnostic work (Reid & Wild 1955) Thus the position of the source and target of a conventional radar display is completely reversed



F g 3 Block d agram of transmitter rece er and d splay system

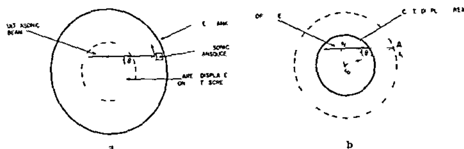


Fig 4 D gr m to llustrat co respondence of path of ultra onic pulse and electron c sweep a) The relat e pos t ons of the t an ducer the ultr son c beam in the wat tank and area displayed on the CRT sc een b) CRT s reen a d weep correspond ng to the pos tion of the ultrason c beam

In addition to the circumferential movement the reversible scanning motion with respect to the radial direction is superimposed on the transducer The resulting position of the ultrasonic beam must then be faithfully reproduced on the CRT with a suitable sweep

Most of the two dimensional or B scan display systems used in ultrasonic diagnoses are limited to a sector of the circle (DONALD & BROWN 1961 HOWRY 1955 DE VLIEGER et coll 1953) and a complete display could be obtained only by suitable superposition of the individual sectors (HOWRY 1955) Recently an electro mechanical (GORDON 1962) and an electronic display with electrostatic beam deflection for a contact scanning system (GREATOREX & IRELAND 1964) were proposed The display system described in the following uses electromagnetic deflection

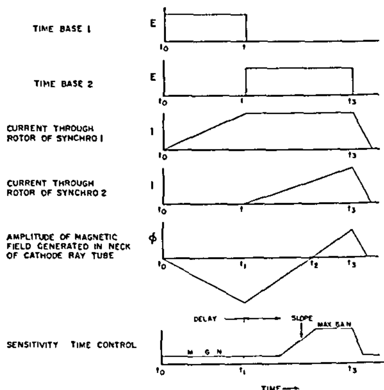


Fig 5 Waveforms illustrating the generation of the sweep and sensitivity time controls

The block diagram of the transmitter receiver and the display system is shown in Fig 3 The transmitter generates a 1 microsecond voltage pulse across a barium titanate transducer which then rings at 2 Mc/s The angle of the beam is $\pm$ 2 2 degrees and the beginning of the far field coincides approximately with the position of the skull in the tank Echoes are received by the same transducer then connected to a receiver tuned to 2 0 Mc/s with a band width of 1 Mc and 80 db gain When an echo is received, the potential of the cathode of the CRT with respect to its grid is lowered, permitting the electron beam to excite a spot on the phosphorescent screen The receiver gain can be adjusted to vary with the timing of the received echoes, thus amplifying more the weak echoes from the inside of the head, and less the strong echo from the skull

In the following the operation of the display system will be described which positions the electron beam in sychronism with the instantaneous position of the transducer The electron beam is normally undeflected and at the center of the screen At the time t_0 (see Fig 4) a sweep waveform from Sweep 1 is applied to the rotor of Synchro 1 (Figs 3 and 5) The resulting three phase

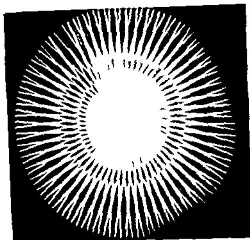


Fig 6 Photograph of display illustrating the superposition of individual sweeps A low PRF was used to separate consecutive sweeps

current is applied to the yoke of the CRT which deflects the electron beam magnetically towards the point A on the perimeter of the CRT This point corresponds to the position of the face center of the transducer which is synchronized with the movement of the rotor of Synchro 1

At the time t_1 the electron beam has reached position A The trailing edge of Time Base 1 waveform is used to generate a synch pulse at the time t_1 This pulse is in turn used to trigger the transmitter as well as the Time Base 2 which then is applied to Sweep 2 The resulting current energizes the rotor of Synchro 2 The rotors of the two synchros are coupled together so that the beam in absence of the additional scanning movement would always be deflected from A towards the center when A travels along the circumference of the circle The stator of Synchro 2 is coupled to the transducer and rocks back and forth with the scanning action of the transducer The resulting three phase currents of Synchro 2 are added to those of the Synchro 1 at that time and generate a suitable magnetic field in the yoke of the CRT which deflects the electron sweep in a direction corresponding to the instantaneous direction of the transducer The superposition of the sweep lines as seen on the screen when the intensity is adjusted suitably is shown in Fig 6

At the time t_2 the electron beam reaches a point equivalent to the distance from the center to A The time required to traverse this distance equals the propagation time of the ultrasonic pulse from the transducer to the center of the tank and back The sweep will usually be continued beyond the center of

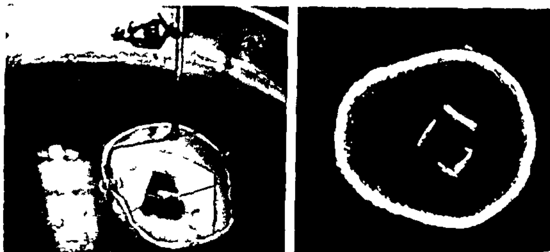


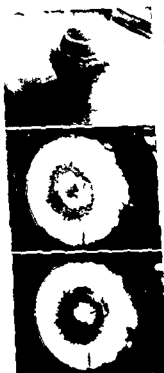
Fig 7 Human skull cap with metal target submerged in water tank and corresponding CRT display showing outline of skull and target

30 CM
6 CM
WATER LEVEL
RUBBER BALL
15 CM DIAMETER
ULTRASONIC TRANSDUCER
PATH OF ULTRASONIC PULSE

6 CM
WATER LEVEL
RUBBER BALL
ULTRASONIC TRANSDUCER

4 CM
WATER LEVEL
RUBBER BALL
ULTRASONIC TRANSDUCER

Fig 8 CRT display of a rubber ball showing ghosts due to reflections from the water surface at various depths and angles of incidence



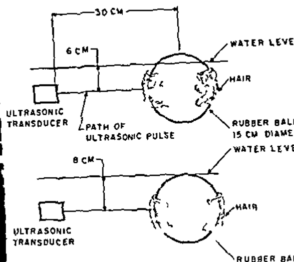


Fig 9 The effect of h ir l ke compound pla ed a ound the ball at d fferent depths and no c dence

the screen The presentation on the screen can be expanded or compress appropriately changing the slope of the Sweep 1 and Sweep 2 waveform brightening pulse is generated at the time t_1 so that the electron beam is v after t and not visible when it is deflected from centre to point A (Fig

Experimental results

The evaluation of the scanner and display system performance is in pr and some results have been obtained The tests carried out to date designed to study the effects of skull attenuation curvature and position tank effects of multiple reflections from tank bottom and water su presence of hair the feasibility of detecting the third ventricle, com referred to as the midline and the temporal ventricles of an average ac

A skull cap immersed in water with a metallic object inside is sho Fig 7 The adjoining picture shows a photograph of the compoun

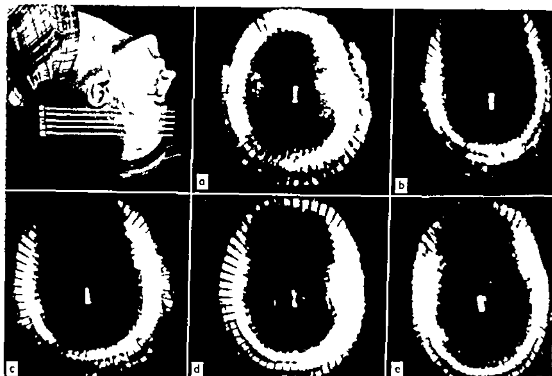


Fig 10 Five images of horizontal head cross sections of a 45 year old male indicated in top left corner Position of forehead is at top

obtained The missing edges of the square could be caused by the oblique incidence on the skull in front of the metallic object

Fig 8 shows the effect of reflections from the water surface obtained with a rubber ball as the target The dashed line indicates a possible path for a reflection from water surface For certain immersion depths a ghost in the center of the picture or a thickening of the walls of the ball is apparent In the third picture both effects are present Similar effects may be expected when reflections from the tank bottom are present Reflections from water surface were not found troublesome, possibly because the angle of the skull with respect to the surface was less than 90 degrees The bottom of the tank was too far away to cause echoes to fall within the image of the skull

The effect of stiff hairlike compound placed around the ball is shown in Fig 9 A depth dependent ghost in the center is also present here, as a result of multiple reflections from this compound and water surface In addition a thickening of the wall and an irregular outline is seen the former probably the result of scatter from this compound and reflections from the water surface In actual practice human hair, when confined closely by a retainer, did not

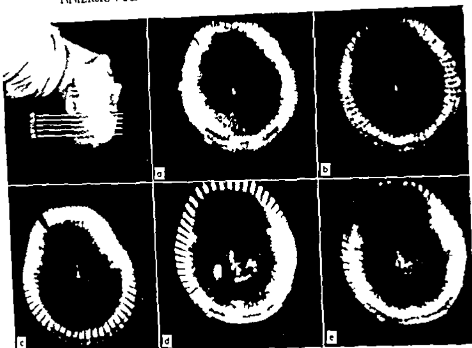


Fig 11 Five images of horizontal head cross sections of a 27 year old male indicated in top left corner Position of forehead is at top

cause much deterioration on the skull outline and did not produce ghosts inside the image

In Fig 10 five horizontal cross sections are shown, obtained at levels indicated on the profile of an adult male aged 45 at the top left corner These levels varied by one centimeter the cross section A was 4 5 cm from the top of the head and the cross section E is 8 5 cm The midline echo was obtained in each case and has left an imprint twice each time the transducer was scanning the left and the right temporal region On cross section D the echo to the left of the midline could have come from the lateral ventricles The differences in intensity and thickness of the skull outline can be explained by the positioning of the head with respect to the tank as depth gain control decreases the amplifier gain further from the center of the display The double outline of the skull in some regions is probably due to multiple reflections within the skull wall

Fig 11 shows similar cross sections The subject was an adult male aged 27 Also here in cross section D there are echoes near the midline particularly marked in this case These echoes have been repeatedly observed in subsequent trials and are believed to originate from the lateral ventricles

Acknowledgements

Thanks are extended to Dr L E Howlett for encouragement and interest in this work and to Mr R R Real Mr A Zuidhof and Mr S K Keays for assistance in testing and construction

SUMMARY

An immersion scanner and display system are described which provide a 360 degree ultrasonic image of a head cross section Effects of multiple reflections from water surface oblique incidence and presence of hair were studied Five head cross sections of male adults aged 45 and 27 are shown In all cases investigated it was possible to obtain an image of the midline

ZUSAMMENFASSUNG

Ein Immersionsscanner und display System wodurch ein 360 Ultraschallbild eines Schadelquerschnittes erzeugt wird werden beschrieben Effekte von multiplen Reflexen von der Wasseroberflache schragem Einfall und Gegenwart von Haaren wurden studiert Funf Schadelquerschnitte von mannlichen Erwachsenen im Alter von 45 und 27 Jahren werden gezeigt In allen untersuchten Fallen war es moglich eine Abbildung der Mittellinie zu erhalten

RÉSUMÉ

Description d un scanner a immersion donnant une image ultrasonique sur 360 d une coupe de la tete Les auteurs ont étudié les effets des réflexions multiples par la surface de l eau de l incidence oblique et de la présence de cheveux Ils présentent cinq coupes de la tete d hommes adultes agés de 45 et de 27 ans Dans tous les cas examinés il a été possible d obtenir une image de la ligne médiane

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FROM THE DEPARTMENT OF NEUROLOGY BOWMAN GRAY SCHOOL OF MEDICINE WINSTON SALEM NORTH CAROLINA AND THE VETERANS ADMINISTRATION HOSPITAL SALISBURY, NORTH CAROLINA U S A

EVALUATION OF FIVE HUNDRED PSYCHIATRIC IN PATIENTS BY MIDLINE ECHOENCEPHALOGRAPHY

by

W M McKINNEY J F TOOLE W T SHARP E A MACMILLAN J W GIBSON and B D SOUTH

I hear beyond the range of sound
I see beyond the range of sight
New earths and skies and seas around
And in my day the sun doth pale this light
Thoreau

Diagnosis of unsuspected space occupying brain lesions in psychiatric patients is difficult A review of reported autopsied psychiatric patients revealed that up to 1 7 % had brain tumor (2) and up to 7 9 % had subdural hematoma (1) Patients in psychiatric hospitals in the United States comprised 51 %, (712 174 patients) of the daily hospital census in 1962 (4) An estimated one out of every ten persons is now suffering from some form of mental illness

Midline echoencephalography offers a safe rapid screening procedure for these patients FORD & AMBROSE reported an overall accuracy for midline shift in 93 8 % of one thousand cases (3)

This is a preliminary report of five hundred ambulatory psychiatric in patients who were screened at the Veterans Administration Hospital Salisbury North Carolina

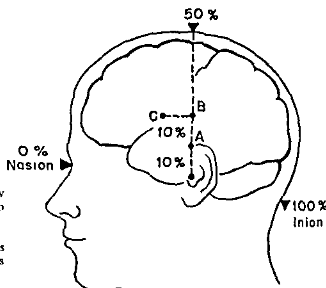


Fig 1 Coordinate system At fifty percent of the distance from nasion to inion a measurement is taken connecting the external auditory meatuses Ten percent of this measurement is used for placement of standard positions A B and C for midline determinations by the coordinate system

Materials and Methods Ultrasonic instruments consisted of a Biosonar 200 by Sonomedic, and a modified Ekoline 20 by Smith Kline Instruments Polaroid ten second film was used for recording Selected cases were studied by averaging multiple exposures on the same film by sweeping with intensity modulation on a modified Ekoline 20 (5) Aquasonic 100 Gel (Parker Laboratories, Inc, Irvington, New Jersey) was used for conduction

For standardization in repeated examinations and correlation of results a coordinate system (5) was used for placement of a 2 25 megacycle transducer Midlines were determined at standard positions A, B, and C (Fig 1)

Head diameters at these positions were measured by calipers to determine the theoretic midline for comparison with ultrasonic midline

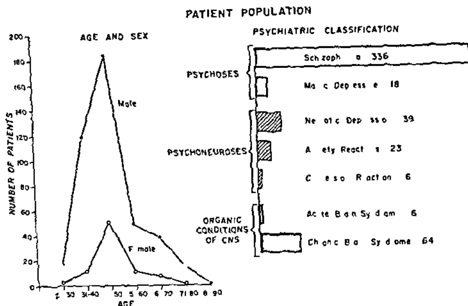
EEG, skull films, and neurologic evaluation by three neurologists were performed on all patients with shifts and borderline shifts and further studies were done as indicated

Patients were ambulatory and are shown with relation to age, sex and psychiatric diagnosis (Fig 2)

Results

In some patients skull thickness and various other factors prevented interpretable tracings in all three positions (position A 418 patients, position B, 451 patients, position C, 171 patients) One or more satisfactory tracings were obtained in all patients

The average midline by ultrasonic and external measurement with calipers



F g ? P t ent populat on Patients re sl own w th relation to age sex and psych atric class fication

in all three positions correlated within one mm (Fig 3) The average measurement connecting the external auditory canals at 50 % of the distance from nasion to inion was 36 3 cm

There was no significant shift to right or left with handedness (see Table)

Twenty five cases were selected for further study Nineteen cases with normal and borderline shifts were evaluated with insufficient evidence to proceed to further contrast studies Six abnormal midline shifts were found and are shown with correlation studies (Fig 4) Two cases were proved to have brain tumor None had calcified pineals

Discussion

The use of midline echoencephalography to screen large population groups for organic brain lesions would seem of value since it is a rapid safe procedure Psychiatric patients offer a very large population group in which organic disease may exist and be difficult to diagnose This study was to determine the usefulness of this procedure on a mass screening basis

A system for examination is most important in reproducing results correlation of data and later follow up The coordinate system used is simple for routine examinations By pathologic correlations usually the echogram in the A

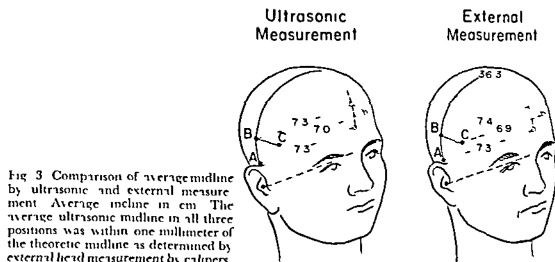


Fig. 3. Comparison of average midline by ultrasonic and external measurement. Average incline in cm. The average ultrasonic midline in all three positions was within one millimeter of the theoretic midline as determined by *external head measurement by calipers*.

position will give echoes from the walls of the third ventricle, in the B position, from the walls of the third ventricle and septum pellucidum, and in the C position, from the septum pellucidum more anteriorly. This provides three determinations of the midline for greater accuracy and establishes a plane to aid in localization. Frontal lesions may shift only the C position without abnormal shifts in positions A or B. The difficulty in obtaining a more anterior position is reflected in our results with only 171 C positions obtained. This may be due to increased skull thickness and curvature as well as other factors. Therefore, frontal lesions may well have been missed in the remaining 329 patients. This is a serious limitation of the current method. In difficult cases with numerous echoes near the midline, averaging the strongest echo by multiple exposures using B mode was of value. Compound scanning by ultrasound may well offer a better screening technique and replace midline echoencephalography in the near future.

Table

Effect of handedness on midline

Handed	Shift	Position (shift in mm)		
		A	B	C
Left (39)	*Right*	*1.1 (9)*	*0.9 (16)*	*1.1 (7)*
	Left	1.4 (19)	1.1 (11)	1.2 (6)
Right (461)	Right	1.2 (129)	1.0 (153)	1.4 (64)
	Left	1.3 (186)	1.1 (155)	1.4 (65)

(dominance (by handedness) did not affect slight shifts within normal limits.)

Posit on of M dl e Sh ft	Sk ll F lm (no calciFed p eals)	EEG	Ne rolog cal	PEG	ART	D agnos s
B	O	O	X	X		Co t cal atrophy
C	O	X	X	X	X	Recu e t Ol go dendrogl oma
B	O	X	O	Perm ss not obta ned fo f rth st d es		
A	O	X	O	X	X	Ast ocytoma
C	O	X	X	X		Co tical atrophy
A	O	X	X		X	Post op an urysm

O Norm l
X Abno m l

Fig 4 Correl tion studies of six abno mal m dl nes None of the pat ents had calcified p neals Two h d bra n tumors

The ultrasonic instrumentation had been calibrated for echoencephalo graphy It was of interest and reassuring to find maximum error of only one mm on comparison of midline by ultrasound and external head measurements

The question of slight shift within the limits of normal (3 mm) being related to dominant hemisphere (as determined by handedness) would appear not true from our data The shift may be to either side

The small number of brain tumors and the fact that no subdurals were found as compared with autopsy series was of interest This may reflect the selection of the ambulatory patients of the hospital as well as limitations in current technique

The procedure was inexpensive rapid and tolerated well by the patients Until better techniques become available midline echoencephalography would appear to be a useful diagnostic tool for screening psychiatric patients

Acknowledgements

The authors wish to express their appreciation to A Patel M D for his assistance in neurologic evaluat on Mrs Bette Pou for her untiring efforts in assisting with examinations preparation of the manuscript and useful suggest ons and to the numerous members of The Veterans Admin st ation who aided in this research project

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SUMMARY

Five hundred ambulatory psychiatric patients were screened by midline echoencephalography for unsuspected organic brain lesions A coordinate system for examination was used Average ultrasonic midline and theoretic midline by external head measurement correlated within one millimeter Handedness did not correlate with slight shift to right or left

ZUSAMMENFASSUNG

Es wurden 500 Patienten wegen nicht verdächtiger organischer Gehirnveränderungen mit Mittellinien echoencephalographie untersucht Für die Untersuchung wurde ein Koordinaten *system verwendet Die durchschnittliche Ultraschall Mittellinie und die theoretische* Mittel linie von den Schädelmessungen stimmten innerhalb der Grenzen eines Millimeters überein Rechts oder Linkshändigkeit hatte keinen Zusammenhang mit geringer Recht oder Links verschiebung

RÉSUMÉ

Cinq cents malades psychiatriques ont subi un examen écho encéphalographique de la ligne médiane pour rechercher des lésions cérébrales organiques Les auteurs ont utilisé un système de coordonnées pour cet examen La ligne médiane écho encéphalographique a coïncidé à moins d un millimètre avec la ligne médiane théorique déterminée par des mesures externes de la tete La droiterie ou la gaucherie sont sans rapport avec un léger décalage à droite ou à gauche de la ligne médiane écho encéphalographique

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FROM THE DIVISION OF NEUROLOGICAL SURGERY AND THE DEPARTMENT OF RADIOLOGY INDIANA UNIVERSITY MEDICAL CENTER INDIANAPOLIS INDIANA USA

SCINTILLOGRAPHY OF INFANTILE SUBDURAL EFFUSIONS AND ITS CLINICAL APPLICATION

by

JOHN MEALEY JR and JOHN A CAMPBELL

Progress in the treatment of persistent subdural collections of fluid in infancy must be based on further knowledge of various pathogenetic factors influencing the course of this disease The most common neurosurgical therapy is excision of the subdural membranes when present to eliminate the presumably restrictive effects of these membranes on the developing brain (5) It has also been suggested that removal of subdural membranes and their abnormally permeable blood vessels could prevent recollections of fluid (4 7) Usually a conventional centrolateral craniotomy is done if subdural membranes are found by exploratory burr holes Recently persistent reaccumulations of subdural fluid and the eventual clinical outcome have been related more to the disproportion between a contracted poorly expansile brain and a larger skull than to the postulated effects of retained subdural membranes (8 11)

The role of neuroradiology in the study and management of subdural effusions in infancy has not been established clearly Since a definitive diagnosis can be made in these cases by a needle puncture contrast procedures such as lumbar encephalography and ventriculography have not been found necessary as a rule or even desirable (5) Subdural air encephalography can visualize

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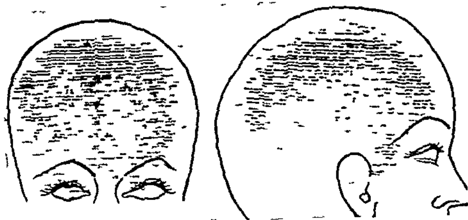


Fig 1 Frontal and lateral dot scans after a right subdural injection of RISA (25 μc) large communicating hematoma

vestigative procedure The subdural scans have been found useful as guides in the neurosurgical management of these patients The characteristics of subdural effusions as delineated on the scans appear to have etiologic and prognostic relevance when correlated with the other clinical data

Material and methods Seventeen of the 25 infants (Table 1) had presumably traumatic effusions o chronic subdural hematomas Subdural taps revealed bilateral hematomas in all but one patient Twenty-eight of the total of 33 left and right sided hematomas were visualized by scanning In the other 8 patients subdural effusions followed bacterial meningitis with Hemophilus influenzae the most common known causative organism In 7 out of 8 patients with post infectious effusions the lesions were bilateral totalling 15 in number of which 11 were scanned

All the patients had previous treatment with multiple taps over varying intervals prior to receiving percutaneous subdural injections of RISA just lateral to the anterior fontanelle The dose of RISA was 20 μc to 30 μc depending on the infant s head size and weight Potassium iodide solution administered before the radioactive injection blocked the uptake of RISA by the thyroid gland

In most infants the head was scanned 4 to 6 hours after the subdural injections using an automatic commercially available scintillation scanner These modifications in the original technique in terms of earlier (rather than at 24 hours after injection) scanning with a more sophisticated apparatus have greatly improved the quality of the scans Print out recordings and photoscans were obtained simultaneously A three by two-inch sodium iodide crystal and 31 hole fine focusing collimator were used Typical control settings were rectilinear scan speed 20—24 cm per minute line spacing 0 3 cm time constant 1/8 second and dot factor [9] The discriminator window was set at 314 KeV

The procedures were carried out under light barbiturate sedation Frontal and lateral scans were performed routinely and usually completed within an hour For the frontal projection the infants were supine with the head flexed on the chest to give a frontobregmatic rather than a true anteroposterior scan The infants were positioned on their sides with the injected hematoma uppermost for the lateral views

Table 1

Type and distribution of subdural effusions in 25 infants

Type	Number of patients		Total left and/or right hemicranial effusions	
	Bilateral	Unilateral	Number	Number scanned
Post traumatic				
Communicating (left right)	6	—	12	12
Lateralized	10	1	21	16
Total	16	1	33	28
Post infectious	7	1	15	11

the intracranial extent of infantile effusions, however, it has never been widely practised despite its usefulness in delineating the fluid collections and brain These attitudes almost certainly have arisen in part because of the morbidity inherent in time consuming air contrast studies in these infants who frequently are severely ill The larger volumes of air which must be exchanged to outline adequately the more extensive subdural effusions are often poorly tolerated

In 1962 it was shown that the size and location of subdural effusions could be accurately visualized by radioactive scanning (6) For this procedure small amounts of radioiodinated (^{131}I) human serum albumin (RISA) were injected percutaneously into the subdural space The labeled albumin was distributed uniformly throughout the subdural fluid collections where it remained in high concentration The activity of RISA in the subdural fluid was 800 to 150 times greater than that measured in the plasma at 4 and 24 hours, respectively Favorable activity ratios of this magnitude made feasible the precise representation of a subdural effusion in situ as a gamma ray image This procedure was found to be safe, convenient, and practicable, and did not interfere with a therapeutic regimen of serial subdural taps

The radiation dose associated with subdural scanning has been measured and is within acceptable levels As calculated from experimental data 30 μc of RISA injected into the subdural space of an infant weighing 7 kg provides a total body dose (beta and gamma radiation) of 0 334 rad (10) However, in practice as soon as scanning is completed, nearly all of the injected radio active material can be recovered by aspiration of subdural fluid Thus, local and whole body irradiation hazards can be virtually eliminated

This is a report of our experiences with subdural scintiscanning in 25 infants observed during the past 2 years No morbidity was associated with this in

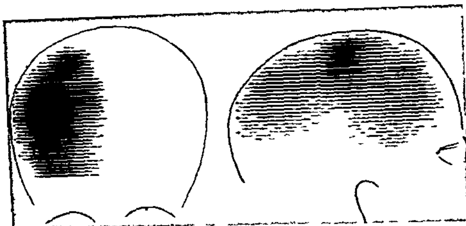


Fig 3 Frontal and lateral photoscans after injection of RISA (30 μc) into the right subdural space show a lateralized hematoma over the entire fronto-parieto-occipital convexity

disproportion The marked cerebral attenuation associated with these infantile subdural hematomas caused a pathophysiological free continuity between the left and right subdural spaces under the inferior margin of the falx

The histories in these 6 cases revealed many similarities These common findings described below seemed in many ways to distinguish clinically infants with diffuse bilateral communicating hematomas from infants whose scans showed more localized subdural effusions Craniocerebral trauma was poorly documented in all 6 patients probably dating to the time of delivery (or earlier) in 5 One infant proved to have a linear skull fracture Measurements of head circumference were not remarkable These infants as a group did not thrive normally following birth Ages at the time of admission to the hospital and establishment of a definitive diagnosis ranged from 6 weeks to 4 months averaging 2 7 months The infants generally were symptomatic for periods of a few days to several weeks prior to hospitalization

Lateralized subdural effusions The scans of the other 19 infants showed subdural effusions in 18 that were non communicating and confined to a hemicranial space These radioisotopic investigations revealed no significant differences between the traumatic effusions (11 patients) and the effusions which followed infection (8 patients) Many scans demonstrated generalized collections of fluid over the entire cerebral convexity (Fig 3) Somewhat more limited effusions were also noted parasagittally over the uppermost frontoparietal aspects of the cerebral hemispheres (Fig 4) However, in about half the scans

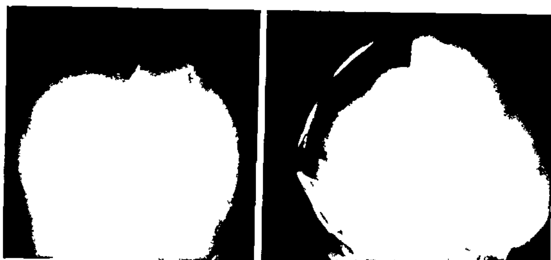


Fig 2 Roentgenograms (brow down) after unilateral injection of air into the subdural space show the bilaterality and extent of the lesion and the size of the cerebral hemispheres

Results

A remarkable diversity in the size and form of subdural effusions was disclosed From the scans the effusions could be classified (Table 1) either as diffuse collections that freely communicated across the midline or as lesions that remained lateralized to the right or left subdural space Twenty craniotomies were performed in 14 infants These direct surgical observations confirmed that scanning gave an accurate representation of the size, configuration, and location of subdural fluid collections The results of subdural scanning and subdural pneumoencephalography agreed in the 3 patients in which both procedures were done The scans and the surgical observations were not completely congruous in only one case This infant had a postmeningitic, anteriorly situated, unilateral subdural effusion of fairly typical serosity which was well demarcated on the scan However, at surgery an encapsulated collection of thick pus was found adjacent and posterior to the site of the effusion This localized subdural empyema was not visualized in the scans

Diffuse bilateral communicating subdural effusions Scanning after unilateral subdural injections of RISA in 6 infants revealed massive generalized subdural effusions which were bilaterally continuous These lesions were presumably of traumatic origin The intracranial extent of this type of hematoma as depicted by scanning is seen in Fig 1 with analogous views of a subdural pneumoencephalogram shown in Fig 2 Although the effusions are symmetrical, their dimensions are greatest over the superior and parasagittal aspects of the cerebral hemispheres the area of maximum craniocerebral

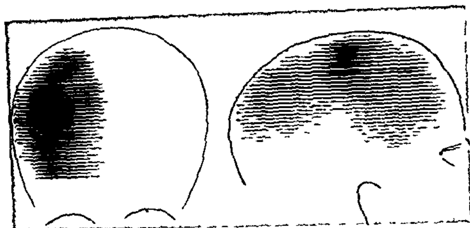


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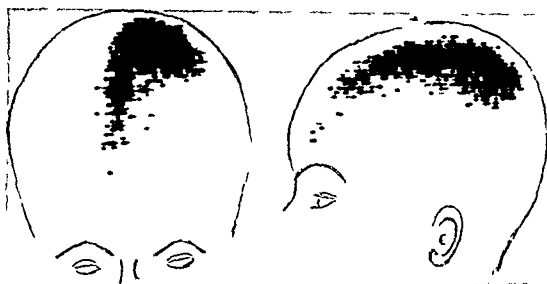


Fig 4 Frontal and lateral photoscans after injection of RISA (30 μc) into the left subdural space Lateralized hematoma is chiefly parasagittal in location

more focal varieties were noted, predominantly anterior or posterolateral The sixteen traumatic effusions that were scanned showed 8 generalized hematomas and an equal number of more limited collections of fluid Fig 5 shows an example of a persistent subdural hematoma that was principally frontal in location The photoscan and lateral skull roentgenogram are superimposed for orientation

In the post infectious group, 6 scans in 4 patients showed fairly generalized subdural fluid collections, and 5 effusions were more localized One patient in this group showed a large effusion over the left cerebral hemisphere which was continuous with a focal collection of fluid over the right frontal pole This was the only example of partial communication between the left and right hemicranial subdural spaces in the 25 infants studied The next two illustrations are examples of more limited types of post infectious subdural effusions In Fig 6 the scans show a laterally placed collection of subdural fluid Most of the lesion is in the parietal area with some parasylvian fronto temporal extension anteriorly Fig 7 shows the lateral scan of a similar type of post meningitic subdural effusion The post operative skull roentgenogram has been superimposed on the scan to show the location of the parietal bone flap turned down in this infant In both of these patients (Figs 6 and 7) successive daily paracenteses lateral to the anterior fontanelles suggested progressively smaller reaccumulations of subdural fluid It was only after subdural scanning that the posteriorly situated, unresolved reservoirs of fluid were disclosed

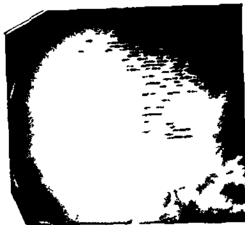


Fig 5 Lateral photoscan showing a subdural hematoma over the right frontal hemisphere with some extension along the sylvian fissure

From the clinical histories the 11 infants with separate lateralized subdural hematomas differed as a group in several ways from the 6 infants whose diffuse bilateral hematomas were in free communication Precipitating craniocerebral trauma was well documented or established in 8 patients A history of injury was not verified in only 3 patients and 2 of these presented with an abnormal increase in head size These 11 infants were older when first seen Postnatal progress was entirely satisfactory as a rule until the onset of the definitive illness Ages at admission ranged from 7 weeks to 12 months averaging 5 6 months Only one child was admitted before the age of 3 months a battered neglected baby who at 7 weeks of age more nearly resembled clinically the type of infants seen with massive communicating hematomas However the generalized bilateral hematomas in this infant were separate

The patients with post infectious subdural effusions were well until the onset of their acute illness A post meningitic etiology was established definitely in 7 and was probable in the other Average age at admission was 5 6 months

Clinical outcome

Table 2 summarizes the surgical results in the 25 infants with subdural effusions who were studied by radioactive scanning In the 6 infants in group I whose scans showed such extensive lesions it did not seem probable that staged bilateral craniotomies could successfully overcome the craniocerebral disproportions and obliterate the subdural spaces In fact one of this group had previously been subjected to these procedures prior to his being included in this study with massive recurrent hematomas Consequently bilateral sub dural pleural or peritoneal shunting procedures were carried out and proved

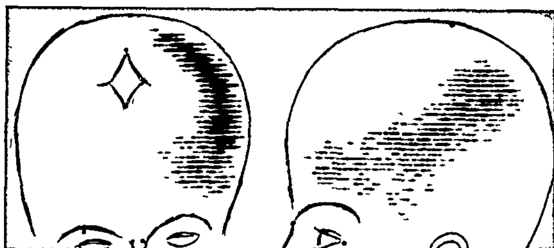


Fig 6 Frontal and lateral photoscans after injection of RISA (30 μc) into the left subdural space in a focal type of post meningitic effusion

satisfactory in preventing reaccumulations of subdural fluid The patency and function of these systems were also tested in several patients by injecting RISA subdurally and probe counting or scanning over the thorax or abdomen Only one of these children was normal in the period of followup The other 5 in this group were obviously defective with one or more manifestations of severe brain damage, such as gross mental retardation, frequent convulsions, blindness, and marked spasticity One infant who was probably only moderately retarded and seemed otherwise to be doing well 2 months after discharge from the hospital died suddenly in his crib from unknown cause

In the 11 infants with other types of subdural hematomas (group II) the initial results were more gratifying Six hematomas in 4 infants resolved with repeated subdural taps These lesions were bilateral in 2 patients, and scanning showed in one a focal anterior and in the other a thin generalized subdural collection of fluid Fourteen craniotomies were carried out in 9 infants The subdural fluid and membranes were removed and the dura was tailored where feasible to approximate the brain more closely, reducing the size of the subdural space All the infants with persistent hematomas had preoperative subdural scans These were used to plan the position of the cranial bone flaps A large central craniotomy was performed for example in the patient whose hematoma is outlined in Fig 3 In contrast, for the lesion shown in Fig 5 a more limited frontal craniotomy via a coronal scalp flap proved entirely satisfactory There were 2 operative deaths, one from shock and hypothermia, and the other from fulminating sepsis In retrospect both fatalities were preventable Eight of the 11 patients in this group appeared to be doing well at

Table 2

Surgical results in 25 infants with subdural effusions

Definitive treatment	Groups I	II	III
Subdural taps	0	4(6)	2(2)
Burr holes	0	0	4(7)
Craniotomies	0	9(14)	5(6)
Shunts	6	0	0
Deaths	1	2	0
Good initial results	1	8	8

Group I = communicating subdural hematomas 6 patients Group II = lateralized subdural hematomas 11 patients and Group III = postmeningitic subdural effusions 8 patients

Figures in parentheses indicate the total number of hemicranial effusions treated individually in each category

the most recent followup Only the battered infant referred to above has obvious mental and motor deficits

The 8 patients in group III the post meningitic effusions all had good initial results following treatment Effusions in two infants were successfully treated with subdural taps Seven effusions in 4 patients resolved after drainage through burr holes Six craniotomies were carried out in the 5 patients whose scans showed larger or persistent subdural effusions The surgical application and technique in this group were essentially the same (Fig 7) as that described for the lateralized subdural hematomas

Comment

Our extended experience substantiates the earlier contention that subdural scanning is a practical new diagnostic method which can aid in the individual surgical management of persistent subdural effusions in infancy Previously subdural pleural shunts have been advocated as treatment for chronic subdural hematomas in infants presenting with enlarged heads and in whom large volumes of subdural fluid continued to reaccumulate following repeated aspirations (9) The distended subdural spaces were visualized roentgenographically by subdural air injections Subdural peritoneal drainage has been used by others initially for large recurrent hematomas and subsequently as a primary operation (2) The surgical indications for the latter were not given



Fig 7 Lateral photoscan after injection of RISA (23 μc) into the left subdural space in a predominantly parietal post meningitic effusion Radiolucent areas demarcate the inferior aspect of the bone flap

Internal drainage was used here as the procedure of choice and successfully resolved all of the large hematomas described in the infants in group I Subdural scans provided specific indications for shunting procedures for this type of communicating hematoma and the coexistent, marked craniocerebral disproportion The bad clinical outcome in 5 of these cases reflected directly the primary influence of underlying brain damage The good result in one child, who is normal at 2 years of age, argues against any deleterious effects attributable to retained subdural membranes The severe clinical sequelae in this group contrast sharply with the satisfactory initial results of treatment in infants with lateralized hematomas These observations emphasize the value of subdural scanning in the prognosis of subdural hematomas in infancy, as an adjunct to the clinical appraisal

In the lateralized subdural hematomas and post meningitic effusions radio active assessment, in situ, also proved very helpful in treatment It seemed reasonable to delay craniotomy in the smaller collections of subdural fluid and seek to resolve these by more conservative methods In some cases, guided by the scans, a more aggressive program of subdural aspirations was carried out, via the metopic, lambdoidal, and inferior coronal sutures as well as adjacent to the anterior fontanelles Eight subdural fluid collections were dried up with taps In none of these was the volume of fluid removed extreme Scans in two infants confirmed the relatively small size of the hematomas In 3 patients who had burr holes over localized varieties of post meningitic effusions shown on the scans the fluid components of these lesions had resolved The residual membranes were not removed Thus our present surgical orientation to infantile subdural fluid collections is not necessarily dependent on the presence or character of the subdural membranes Treatment is more directed



Fig 8 Aborted fetus at 3 5 months (crown rump length 9 5 cm) with calvarium and dura removed A s bdural hematoma overlays the right hemisphere Transluce it membranes extend over most of the cerebral convexi t es A smaller clot over the left s lvian area is not clearly v sible (Courtesy of Dr WILLIAM E DEMYER)

at overcoming the craniocerebral disproportion and obliterating the enlarged subdural space In the lateralized traumatic and post meningitic effusions that do not respond to the simpler measures described above good results follow evacuation of the fluid (and part of the membranes) and dural tailoring via craniotomy Subdural scanning gives unique aid in this regard in planning the type of cranial bone flap

The significant differences in histories and morbidity in the two groups of subdural hematomas reported here emphasize the different pathogenetic mechanisms in this disease There is a striking similarity between our results predicated by observations on the scans and the clinicopathological studies in a surgical series of 24 infants with chronic subdural hematomas reported recently by CHRISTENSEN & HUSBY (1) The prognosis in their cases was correlated with the condition of the brain and specific pernicious effects from retained subdural membranes were largely discounted These authors classified most of their patients into those with pre and perinatal head injuries and infants with probable postnatal trauma Cases in the former groups were seen earlier (mean age 4 months with the perinatal lesions) and had uniformly bad results following treatment This experience is duplicated in 5 of 6 patients



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In the lateralized subdural hematomas and post meningitic effusions radioactive assessment, in situ, also proved very helpful in treatment It seemed reasonable to delay craniotomy in the smaller collections of subdural fluid and seek to resolve these by more conservative methods In some cases, guided by the scans, a more aggressive program of subdural aspirations was carried out, via the metopic, lambdoidal and inferior coronal sutures as well as adjacent to the anterior fontanelles Eight subdural fluid collections were dried up with taps In none of these was the volume of fluid removed extreme Scans in two infants confirmed the relatively small size of the hematomas In 3 patients who had burr holes over localized varieties of post meningitic effusions shown on the scans the fluid components of these lesions had resolved The residual membranes were not removed Thus our present surgical orientation to infantile subdural fluid collections is not necessarily dependent on the presence or character of the subdural membranes Treatment is more directed

RÉSUMÉ

Présentation de 25 nouveaux cas de gamma-encéphalographie d épanchements sous-duraux chez des nourrissons après injection de RISA dans l espace sous-dural Ces scintigrammes ont été classés et confrontés avec l histoire clinique et l effet du traitement Cette nouvelle technique s est montrée utile pour guider le traitement chirurgical de ces malades L analyse de nos cas nous fait penser que les renseignements tirés du scintigramme sous-dural sont applicables au pronostic et à l étiologie des hématomes sous-duraux chroniques du nourrisson

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presented here with radioactive studies showing extensive communicating subdural hematomas. Their cases with probable postnatal head trauma presented after 6 months of age on the average, occasionally had increased head circumference, *and had generally good results after treatment.* *These reported* data are identical to our experience in the 11 infants with lateralized subdural hematomas shown by scanning.

Other observations on the prenatal incidence of subdural hematomas have been *made at this medical center by* Dr. WILLIAM E. DEMYER *in studies of* human fetal teratology (3). A number of aborted fetuses have shown fairly typical hematomas on gross neuropathological examination. Head injury incident to uterine expulsion through a tight cervical os cannot be excluded with certainty as the acute traumatic etiology in some of these specimens. However, in other fetuses more chronic appearing hematomas with translucent membranes have been demonstrated grossly (Fig. 8). Histological studies of this material are in progress to determine more exactly the age and pathomorphology of these lesions. These observations suggest tentatively the occurrence of subdural hematomas in the viable fetus, in utero, as early as the end of the first trimester of pregnancy. Pathogenetic mechanisms remain obscure. More specifically, possible correlation of these data with the poor prognosis found in infants with extensive subdural hematomas presenting soon after birth (group *I*) is an attractive hypothesis.

Acknowledgement

This work was supported in part by U.S.P.H.S. Grants H 6308 and CA 06145 from the National Institutes of Health, Bethesda, Maryland.

SUMMARY

Further experiences with gamma ray scanning of subdural effusions after injection of RISA into the subdural space are reported in 25 infants. Scans were classified and correlated with the clinical histories and responses to treatment. This new procedure proved valuable as a practical guide in the surgical management of these patients. Analysis of our material suggested that *information gained from subdural scanning is relevant to the prognosis* and etiology of chronic subdural hematomas in infancy.

ZUSAMMENFASSUNG

Die Mitteilung *berichtet über die Erfahrung mit der Gammastrahlen* Scan Methode an 25 Kindern nach Einspritzung von RISA in subdurale Ergüsse. Die Scans wurden tabuliert entsprechend den klinischen Befunden und entsprechend den therapeutischen Resultaten. Diese neue Methode erwies sich nützlich zur Bestimmung des chirurgischen Vorgehens in diesen Fällen. Die Analyse unseres Materiales erweist, dass die Methode wertvoll für die Prognose und für die Abklärung der *Ursachen der subduralen Hämatome im* Kindesalter ist.

FROM THE RADIOLOGY AND RADIUM INSTITUTES (DIRECTOR PROF. A. BOLLINI), CLINIC FOR NERVOUS AND MENTAL DISEASES (DIRECTOR PROF. C. AMBROSETTO), AND TEACHING ON NUCLEAR PHYSICS APPLIED TO MEDICINE (DIRECTOR IN CHARGE PROF. G. TORI), BOLOGNA UNIVERSITY, BOLOGNA, ITALY

SCINTISCANNING OF CEREBRAL NEOPLASMS BY RADIOACTIVE MERCURY (NEOHYDRIN ^{203}Hg)

by

F. Morello, G. P. Giordano, C. Alvisi and R. Sciascia

Our experience with radioisotopic diagnosis of cerebral neoplasms is relatively short, but we wish to report our results from the use of radioactive mercury.

In 1960 Blau & Bender used Neohydrin ^{203}Hg as a new detector for localizing cerebral tumours; this detector has been suggested by an Oak Ridge group as an ideal tracer for gammascan techniques. Subsequently Brinkman, Wegst & Kahn (1962), Croll, Brady & Hand (1962), McGinnis, Eyler, Du Sault & Kristen (1963) and Sklaroff, Polakoff, Lin & Charkes (1963) submitted their observations.

The advantages of Neohydrin ^{203}Hg over serum albumin labelled ^{131}I (R.I.S.A.) are not due to a higher specificity, but to more suitable physiological and biological characteristics of the ^{203}Hg as compared with R.I.S.A.

The average life of ^{203}Hg is 15 days with a single gamma output of 208 KeV and low energy beta radiation. The single gamma ray of ^{203}Hg can easily be

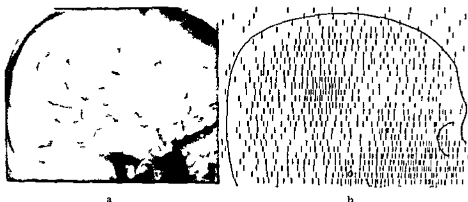


Fig 1 Right temporo-parietal glioblastoma a) The carotid angiogram in the capillary phase shows a number of neoformed vessels arranged coil like b) Corresponding scan

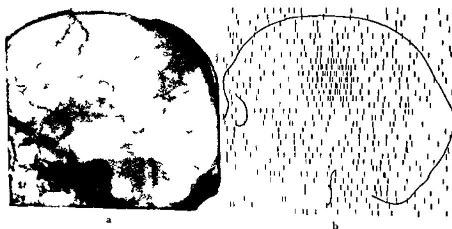


Fig 2 Left fronto parietal glioblastoma a) The carotid angiogram in the venous capillary phase shows number of artero-venous shunts b) Corresponding scan

collimated and the scatter problems are minimal The low energy of beta particles of ^{203}Hg reduces the irradiation to the patient

The disadvantage of the rather long physical average life of ^{203}Hg is partly corrected by incorporating ^{203}Hg with a compound having a short biological average life Neohydrin ^{203}Hg (3 chloro mercury 2 metoxipropylurea) in fact is quickly excreted 50 % of the dose is discharged during the first 8 hours and the remainder within an average time of 3 days after 5 hours the hematic radioactivity is 10 to 16 % of the administered dose and falls to 4 1 % after 24 hours

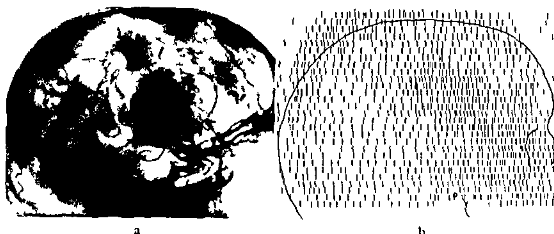


Fig 3 Right fronto parietal glioblastoma after partial surgery a) The carotid angiogram shows pathologic circulation due to residual neoplasm b) Corresponding scan

Consequently the total irradiation dose to the patient is on the whole less than with R I S A

The experimental findings show an improvement of the $\frac{\text{target}}{\text{non target}}$ rate on the side of Neohydrin ^{203}Hg Radiation dose for the kidney 10 % of the Neohydrin ^{203}Hg is taken up by the kidney, with a biological average life of 28 days The radiation dose for the kidney, the average dose being 10 μCi kg , seems to be 35 to 40 rad When administering mercurial diuretics (steady mercurhydrin) the day before scan, urinary secretion during the following 48 hours increases from 11 to 32 % and the radiation dose to the kidney decreases to about 15 to 25 rad

In short, the quick hematic clearance and the efficiency of collimation and screening of the ^{203}Hg mono energetic gamma rays seem to offer a better means for demonstration of cerebral tumours, with a safer radiation dose

Up to now, results have been significant but not exceptional

Technique of the examination In order to keep down the renal uptake of the isotope we have given an intramuscular injection with 1 ml of steady Neohydrin, or a similar detector having the property of reducing the renal uptake of the isotope, 24 hours before endovenous injection of 10 μCi/kg of Neohydrin ^{203}Hg (maximum dose 700 μCi), carrying out scan 2 to 4 hours later We have employed an automatic scanner simultaneously performing the dotscan and the photoscan (19 holes focusing collimator with 2 5 cm lead screening, collimation depth 5 to 7 cm , collimator head distance 1 to 3 cm Sodium iodide crystal activated with Tallium 50 KeV spectrometric window focused

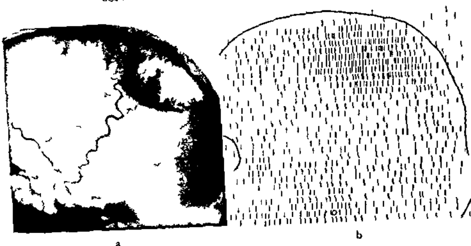


Fig 4 Left parietal meningioma a) Structural alterations of the cranium selective catheterisation of the external carotid shows impregnation of the contrast medium through the tumour b) Corresponding scan

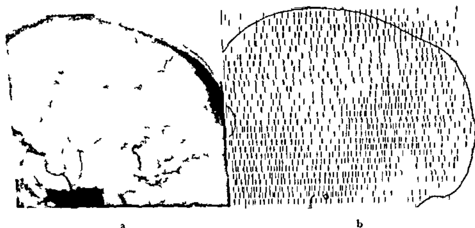


Fig 5 Left occipital meningioma a) Rounded osteolytic zone in the occipital region arteriography of the external carotid shows a pathologic halo like reticulation b) Corresponding scan

on the 230 keV photopeak of [203] Hg) The scan is carried out in the two a p and lateral projections Reference marks external auditory meatus, mastoid apex head summit glabella a p pupils, occipital tuberosity, zygomatic root Time 30 to 40 minutes for each projection

Material The scintiscanning was carried out on 22 patients with brain neoplasm All the cases had been previously submitted to carotidography

in order to compare the two methods as to results After these examinations, all the patients were submitted to surgery, with the exception of one case, a patient with astrocytoma in whom the scintiscanning was carried out after a necessarily partial operation

Histologically, the cases were classified as follows 11 glioblastomas, 4 meningiomas, 3 astrocytomas, 2 neurinomas, and 2 brain metastases The seat of these brain neoplasms was almost always supratentorial

Results

Our cases were too small in number to permit a percentage computation of the results for the various histologic types The overall percentage of positivity was 80 % The higher storage of the radioisotope was found in the less differentiated tumours Extremely high concentration was noted in glioblastomas (Figs 1, 2, 3), meningiomas (Figs 4, 5), and metastases, in astrocytomas the concentration was moderate The findings were negative in acoustic neurinomas In our examinations, no disturbances were noted

In the literature referring to the use of Neohydrin ^{203}Hg, high percentages of positive results have been noted BLAU & BENDER (1960) reported 85 % (100 cases), BRINKMAN et coll (1962) 65 % (92 cases), CROLL et coll (1962) 70 % (17 cases), and SKLAROFF et coll (1962) 83 % (20 cases)

Conclusions

Although our experience is still rather limited we feel that the radioisotopic method is a sound diagnostic test which may be useful as a complement to the traditional angiographic and pneumographic examinations, though it does not claim to replace them

Although at present the best results are obtained in highly vascularized neoplasms, a satisfactory demonstration is also achieved in tumours with relatively moderate circulation The method can also give some information on the nature of the tumour With some locations, the topographic indications are sufficiently clear for clinical purposes whereas with others the result is not so satisfactory

SUMMARY

In the diagnosis of intracranial neoplasms the authors have made use of scintiscanning as an aid to the traditional neuroradiological examinations As a tracer they employed radioactive mercury (Neohydrin ^{203}Hg) To demonstrate and record the radioactivity they used an automatic scanner and scintiscans and photoscans were carried out Positive results were noted in glioblastomas meningiomas metastases and astrocytomas

ZUSAMMENFASSUNG

Zur Diagnose von intracraniellen Neoplasmen wurde unterstutzend zu den traditionellen neurologischen Untersuchungen Szintigraphie durchgefuhrt Als tracer kam radioaktives Quecksilver (Neohidrin ^{203}Hg) zur Verwendung Fur die Demonstration und Aufzeichnung der Radioaktivitat verwendeten die Autoren einen automatischen Scanner es wurden Scintigramms und Photoscans angefertigt Positive Ergebnisse erhielt man bei Glioblastomen Meningeomen Metastasen und Astrocytomen

RÉSUMÉ

Les auteurs ont utilisé la scintigraphie comme complément des examens neuroradiologiques traditionnels pour le diagnostic des néoplasies intracraniennes Ils ont employé comme traceur le mercure radioactif (Neohydrine ^{203}Hg) et pour la détection et l'enregistrement de la radioactivité un scanner automatique Ils ont obtenu des resultats positifs dans des glioblastomes des méningiomes des métastases et des astrocytomes.

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ISOTOPE ENCEPHALOMETRY
A SIMPLIFIED AND RAPID SCANNING PROCEDURE

by

KARE MYHRE

During the last 10 years, about 1 000 patients have been examined by isotope encephalometry. An automatic scanner was provided a year ago. According to the procedure formerly used the patient was examined in a supine position, 2 hours and 24 hours after an intravenous injection of 150 to 200 μCi of radioactive, iodinated serum albumin. A transparent plastic plate of rectangular shape was positioned on either side of the head, partly to stabilize the head and partly to define the fields to be examined. Twelve spots on one side of the cranial vault were selected and marked on one of the plates. The positions from one plate were transferred to the other one by means of a 'back pointer', so that exactly corresponding positions could be ascertained. A difference in activity of 10 % or more between corresponding spots was regarded as a positive finding. This indicated either a tumor, an abscess, or a haemorrhage. A clue with regard to aetiology could be obtained by comparing the findings at 2 hours with those at 24 hours or by repeating the examination 3 weeks later.

Of approx. 1 000 cases examined, 535 were available for evaluation. A tabular compilation is presented below showing the number of the different types of brain tumor found in this material.

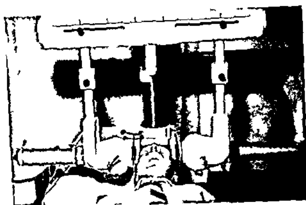


Fig 1 Automatic scanner for isotope encephalometry

Type	Number	Found
Glioblastoma multiforme	81	67
Astrocytoma	20	10
Oligodendroglioma	12	5
Metastases	23	18
Meningeoma	38	25
Meningeosarcoma	4	3
Medulloblastoma	1	1
Ependymoma	1	0
Totals	180	129

It is *evident that* slow growing tumors such as astrocytomas and oligodendrogliomas frequently escape detection

The automatic scanner (from Frisecke Hoepfner Germany) is ordinarily equipped with only one scintillation counter A supporting arm for 2 scintillation counters was constructed in Norway (*Fig* 1) The two counters move in a vertical plane on opposite sides of the head with the patient in a supine position The speed is 2 to 3 *mm/sec* and the distance between horizontal scanning lines is 10 mm The scanner is equipped with a magnetic and photoelectric recorder and a mechanical printer The photoelectric record is made inside a square light tight box with the film in a frame beneath the top With the patient resting upon the box a roentgenogram of the organ to be examined can be made on the same film as the photorecord The background is subdued by adjustments of the current to a decharging tube

A useful unit of the scanner is the differential scaler A deliberate number of pulses per second may be fed to this scaler These pulses are automatically subtracted from those counted thus permitting small differences in activity to



Fig 2 Roentgenogram of the skull with a black area representing a tumor

be recorded This is of especial value in the scan of a voluminous organ such as the liver

The unit can be used to subtract the counts of one scintillation counter from those of the other one Fig 2 shows a film of the skull with a black area corresponding to a tumor The elimination of background is obvious The picture was made by superimposing the photoelectric record on a roentgenogram and making an exposure with a Polaroid camera With negative findings the scan must be repeated and this time the former subtrahend is now subtractor

When interest is focused mainly on brain scans, a rapid scan can be made using a simple electronic circuit Two scintillation counters with separate ratemeters are used, often combined with two pulse height analyzers The currents from the ratemeters counteract each other by means of an electronic device When equal activities are present no current is produced A difference in activity of 10 % or more results in a current shown by deflexion of the pen of a recorder The zero line is adjusted by a potentiometer to the center of the paper The deviations to either side of the zero line indicate the side location of the isotope concentrating process If the recorder runs at the same speed as the counters, the exact location is easily disclosed

A similar principle may be used in photoelectric recording The tube can be turned in two opposite directions by means of an electromagnet, depending upon the prevailing current The rectangular oblique light imprints on the film will accordingly be different

Addendum

The photoscan has recently been modified Instead of one decharging tube two tubes are used each of them connected to separate units consisting of a counter and a ratemeter When *the currents from the units* are brought in opposition by a device the prevalent current will decharge the tube to the unit registering the strongest activity As only one half of the film 40 × 40 cm is assigned to each tube a black area on either *the upper or the lower* part of the film will disclose the exact position of a process in the brain The use of the two units *independently* and simultaneously will reduce the scan time of symmetrical organs to half that required when only one unit is used

SUMMARY

A commercial scanner equipped with two units each consisting of a counter a ratemeter and a decharging tube has been used The currents from the units are put in opposition and the prevalent current is demonstrated either by deflecting the pen of a recorder to the left or right of the zero line or by activating a decharging tube As only one half of the film 40 × 40 cm is assigned to each tube the position of a black area will indicate the exact location of the process in the brain.

ZUSAMMENFASSUNG

Ein im Handel befindlicher Scanner wird mit zwei Kompon nten jede bestehend aus einem Zahler einem Mittelwertmesser und einem entladenden Rohrchen ausgerustet Wenn die Strome d r beiden Komponenten gegeneinander gerichtet sind wird entweder der vorher schende Strom den Feder eines Aufzeichners nach einer von zwei Seiten verschoben oder das entladende Rohrchen aktiviert Da nur die eine Halfte des Filmes 40 × 40 cm von jedem Rohrchen beleuchtet wird kann die Position einer geschwartzen Flache eine Anzeigung fur die genaue Lokalisation eines Prozesses im Gehirn geben

RESUME

Un appareil commercial pour balayage linéaire est équipe avec deux assemblages chaque comprend ant un compteur un intégrateur et un tube a décharges Les courants des deux assemblages sont mises en opposit on et le courant dominant est demontré ou par un enregis trateur dont la plume se deplace a l une ou l autre direction ou par le décharge d un des deux tubes Par le fait que seulement un demi part du film est assigne a chaque tube un endroit noir sur le film indique la localité exacte d un procés cérébral

FROM THE DEPARTMENT OF NEUROSURGERY AND THE PHYSICS RESEARCH LABORATORY, MASSACHUSETTS GENERAL HOSPITAL, BOSTON, MASSACHUSETTS, U S A

SCANNING WITH POSITRON-EMITTING ISOTOPES IN CEREBROVASCULAR DISEASE

by

ROBERT G OJEMANN, SAUL ARONOW and WILLIAM H SWEET

Most reports on brain scanning have been limited to the use of this procedure in the diagnosis of intracranial tumors Relatively little attention has been directed towards its value in the assessment of patients with cerebrovascular disease

During the past 8 years more than 4,000 brain scans have been performed at the Massachusetts General Hospital using the positron emitting isotopes ^{74}As and ^{64}Cu In this group there were 54 scans on 48 patients with confirmed diagnoses of aneurysm arteriovenous malformation, subarachnoid hemorrhage or intracerebral hemorrhage (Table 1) and 146 scans of patients with a history and clinical findings which pointed to the likelihood of occlusive cerebral vascular disease, e g either the sudden onset of a neurologic deficit followed by stabilization or some degree of recovery, or transient attacks of neurologic deficit presumably on an ischemic basis (Table 2) The important findings are summarized in this report Detailed analyses of our results are reported elsewhere (28, 29)

Method

Several previous reports have discussed our use of positron emitting isotopes for localization of focal intracranial lesions (2, 24, 28, 29, 35) Two isotopes,

^{74}As as sodium arsenate and ^{64}Cu chelated with DTPA (diethylenetriamin pentacetic acid) have been used most frequently

Localization with positron emitting radioisotopes utilizes the peculiar physical properties of the positron electron annihilation process This reaction yields a pair of oppositely directed gamma rays which are recorded when they hit a pair of detectors in time coincidence This record is called a positrocephalogram (PCG) In addition, the difference in total gamma activity between one side of the head and the other may be recorded This unbalance scan, or asymmetrogammagram (AGG), indicates the asymmetry of a concentration of activity which is right or left sided The two scans, PCG and AGG are printed simultaneously by mechanical printers directly connected to the moving detector heads so that a full sized lateral picture is immediately available An a p view may also be obtained The radioisotope is administered by intravenous injection and the scan is performed about one hour after injection

Scans are interpreted by describing the locus of the concentration and the degree of abnormality is reported on a 1 to 4 scale 1 indicates a definitely abnormal scan 2 probably abnormal scan, 3 probably normal, and 4 a definitely normal scan For statistical purposes 1 and 2 are called abnormal, 3 and 4 are normal No clinical interpretation is given of the abnormal scan, although the character of the concentration of the printed markings may present a useful diagnostic clue

In order to correlate scan abnormality and neurologic status an arbitrary division into a Mild 'Moderate and Severe clinical deficit has been made In general, patients with a severe deficit had complete or nearly complete hemiplegia or homonymous hemianopsia or evidence of severe sensory impairment or aphasia when the dominant hemisphere was involved or severe disturbance of mentation Patients with lesser degrees of clinical dysfunction (28) were placed in the moderate and mild groups

Results

Aneurysm and subarachnoid hemorrhage Review of the literature has revealed that scans using all types of isotopes had been reported in 58 patients with known intracranial aneurysms (3 5 6 7 8 10 12 17 18 22 23 30 31 32 33 35 36 37) Twenty one of these were abnormal The largest previous series was reported by PLANIOL & GAUTHIER (31) who used radioactive iodinated serum albumin and demonstrated 3 positive studies in 13 cases of arterial aneurysm

Fourteen of our patients had a history of subarachnoid hemorrhage associated with some degree of neurologic deficit due to cerebral injury and demonstra

Table 1

Radioisotopic scans in patients with aneurysm, arteriovenous malformation, subarachnoid hemorrhage and intracerebral hemorrhage

Disease category	^{74}As		^{64}Cu		Total
	Abnormal	Normal	Abnormal	Normal	
Aneurysm					
With subarachnoid hemorrhage and neurologic deficit	8	3	1	2	14
With subarachnoid hemorrhage and third nerve palsy	0	1	0	2	3
Without subarachnoid hemorrhage	3	0	1	0	4
Arteriovenous malformation	3	1	0	1	5
Intracerebral hemorrhage	12	5	4	7	28
Total	26	10	6	12	54

tion of an aneurysm on arteriography. Eight of 11 arsenic and 1 of 3 copper scans were abnormal. The aneurysms ranged in size from 2 × 3 mm to 17 × 14 mm. In no case was the outline of the aneurysm demonstrated. The positive scans instead demonstrated increased concentration in the cerebral tissue adjacent to the aneurysm or in the tissue supplied by the vessel harboring the aneurysm. Subsequent studies of many of these cases showed intracerebral hemorrhage and/or infarction. Fig. 1 illustrates such a case where cerebral infarction followed rupture of a middle cerebral aneurysm. However, infarction and hemorrhage could not be differentiated on the scan.

Three patients with aneurysms of the internal carotid artery had subarachnoid hemorrhage, but a third nerve palsy was their only neurologic abnormality. All had normal scans (1 arsenic and 2 copper).

Four abnormal scans were obtained on 3 patients who had demonstrated aneurysms but no hemorrhage. Two of these patients had been admitted for evaluation of seizures, and their positive arsenic scans led to additional diagnostic studies. In one, isotopic localization was in the left temporal area, and the arteriogram revealed a large middle cerebral arterial aneurysm. In the other, isotopic concentration indicated abnormality in the left temporal parietal region, and a calcified lesion removed at operation proved to be an aneurysm on pathologic examination. This scan is illustrated in Fig. 2. The third patient had a 3 × 4 cm aneurysm of the basilar artery which was almost completely filled with thrombus. In this case the area of increased concentration seen in the scan may have represented the large thrombosed aneurysm, the compressed tissue, or both.

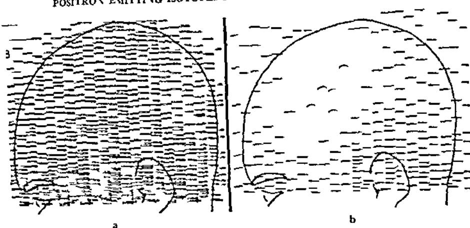


Fig 1 Ruptured middle cerebral aneurysm with associated infarct on in cerebral tissue supplied by this vessel a) Positrocephalogram (PCG) Increased concentration in the infer or frontal parietal a a b) Assymetrog mmagram (AGG) Striking abnormality in the frontal parietal area The diffuse distribution of the straight symbols indicates the head is slightly off to the left side the localized area of absence of these marks and the presence of the curved marks indicates a definite right sided abnormality

Arteriovenous malformation Fifty of 73 reported scans were abnormal in patients with arteriovenous malformation (1, 3 5 7 8 10 11 12 15, 17, 21 22 25 26 27 30 31 32 34 35 37) Again the largest group was reported by PLANIOL & GAUTHIER With RISA 24 of 28 scans were abnormal (31) In our series (Table 1) the 3 patients with intracerebral arteriovenous malformations had abnormal arsenic studies The normal arsenic study was in a patient with an epidural extracranial malformation The patient with the normal copper study had no symptoms referable to the malformation which measured 1 × 3 cm and was an incidental finding at arteriography

Spontaneous intracerebral hemorrhage In the literature 25 of 39 intracerebral hematomas were associated with an increased isotopic concentration (3 5 6 7 8 10 11 14 15 17 18 21 22 26 27, 30 31 35) We have evaluated 23 patients with spontaneous intracerebral hemorrhage principally due to hypertension with 28 scans

In the group of patients with severe neurologic deficit at the time of the scan 9 of 12 arsenic but only 1 of 4 copper studies were abnormal (Table 3) Seven of the patients with abnormal arsenic scans had putaminal hemorrhages (16) Normal arsenic studies were found in 2 patients with putaminal hemorrhages and in 1 patient with a cerebellar hemorrhage In all but one abnormal study the area of localization delineated the site of pathology which had been

Table 1

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tion of an aneurysm on arteriography. Eight of 11 arsenic and 1 of 3 copper scans were abnormal. The aneurysms ranged in size from 2 × 3 mm to 17 × 14 mm. In no case was the outline of the aneurysm demonstrated. The positive scans instead demonstrated increased concentration in the cerebral tissue adjacent to the aneurysm or in the tissue supplied by the vessel harboring the aneurysm. Subsequent studies of many of these cases showed intracerebral hemorrhage and/or infarction. Fig. 1 illustrates such a case where cerebral infarction followed rupture of a middle cerebral aneurysm. However, infarction and hemorrhage could not be differentiated on the scan.

Three patients with aneurysms of the internal carotid artery had subarachnoid hemorrhage, but a third nerve palsy was their only neurologic abnormality. All had normal scans (1 arsenic and 2 copper).

Four abnormal scans were obtained on 3 patients who had demonstrated aneurysms but no hemorrhage. Two of these patients had been admitted for evaluation of seizures, and their positive arsenic scans led to additional diagnostic studies. In one, isotopic localization was in the left temporal area, and the arteriogram revealed a large middle cerebral arterial aneurysm. In the other, isotopic concentration indicated abnormality in the left temporal parietal region, and a calcified lesion removed at operation proved to be an aneurysm on pathologic examination. This scan is illustrated in Fig. 2. The third patient had a 3 × 4 cm aneurysm of the basilar artery which was almost completely filled with thrombus. In this case the area of increased concentration seen in the scan may have represented the large thrombosed aneurysm, the compressed tissue, or both.

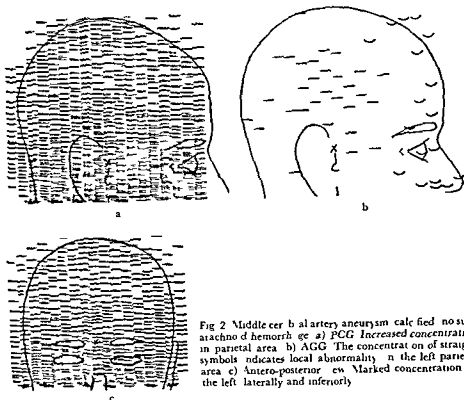


Fig 2 Middle cer b al artery aneurysm calc fied no subarachno d hemorrh ge *a) PCG Increased concentration in parietal area* b) AGG The concentrat on of straight symbols ndicates local abnormality n the left parietal area c) Antero-posterior ew Marked concentration on the left laterally and inferiorly

10 12 13 15 17 19 20 22 23, 24 32 33, 34, 35 36) For the most part these reports do not draw conclusions about the diagnostic value of scanning in these disorders RUSHTON (33) discusses 22 patients thought to have had either a thrombotic or embolic stroke In 9 patients where the lesion was at least six weeks old at the time of the scan no abnormality was seen In 13 patients the onset of symptoms had occurred less than six weeks before the study, and in 4 increased isotopic concentration occurred in the appropriate brain region

In our series 86 patients had a clinical diagnosis of cerebral infarction and a neurologic deficit at the time of the scan which persisted with little or no improvement (Table 2) In the group with a severe neurologic deficit 11 of 12 ⁴As scans were abnormal (Table 4) while only 3 of 8 ⁴Cu chelate studies were positive The area of increased concentration was in good agreement with that suspected on the basis of the clinical picture Fig 3 demonstrates an abnormal arsenic scan from this group and illustrates the clear degree of

Table 2

Radioisotopic scans in patients with cerebral vascular occlusive disease

Disease category	No of cases	^{74}As		^{64}Cu		Total cases
		Abnormal	Normal	Abnormal	Normal	
Thrombosis permanent deficit						86
Intracranial occlusion	71	34	15	9	13	
Carotid occlusion	15	10	1	—	4	
Thrombosis temporary deficit	25	7	8	1	9	25
Transient ischemic attacks						22
Carotid region	15	2	10	—	3	
Vertebral basilar region	7	1	3	1	2	
Embolism						
Permanent deficit	9	—	6	—	3	13
Temporary deficit	4	—	1	—	3	
					Total	146

suspected on the basis of the clinical examination or determined at arteriography or operation

The temporal relationship between onset of symptoms and the radioisotopic study was evaluated During the first week after onset of symptoms, considering all degrees of deficit together, only 5 of 10 arsenic and 1 of 6 copper scans were abnormal None of these was classified as '1 (definitely abnormal) During the second and third weeks after hemorrhage, all scans were abnormal (3 copper and 7 arsenic) Four of the arsenic studies were classified as '1

Multiple serial scans in 3 patients confirmed the superiority of ^{74}As over the ^{64}Cu chelate They also demonstrated an increasing degree of abnormality from the first to the second week after onset

In 2 patients tissue samples taken during operative removal of the hematoma indicated that the cerebral tissue immediately adjacent to the hematoma contained 5 to 20 times more isotope than the hematoma itself This was true for both the ^{74}As and the ^{64}Cu chelate

Cerebral thrombosis A number of reports have described small numbers of patients who were scanned following cerebral infarction (2, 3 4, 5, 6, 7 8, 9,

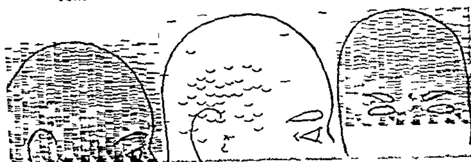


Fig 3 Abnormal arsenic scan permanent deficit thrombosis of the middle cerebral artery *Left* PCG Posterior temporal parietal concentration *Center* AGG Concentration of curved marks indicates right sided unbalance *Right* Right lateral inferior concentration

Embolism In 13 cases with a clinical diagnosis of cerebral embolism the 7 arsenic and 6 copper scans were normal Nine patients had permanent deficits of which 4 were severe and 5 moderate The time from onset of symptoms to scan ranged from one day to 2 years Four other patients had temporary deficits followed by recovery The reason for this striking lack of abnormality was not apparent from the clinical or pathologic evaluation

Discussion

Radioisotopic scans utilizing ^{74}As are abnormal in a high percentage of patients having a neurologic deficit and subarachnoid hemorrhage from an aneurysm The area of increased isotopic concentration is located in the region adjacent to the aneurysm or in the area of brain tissue supplied by the parent vessel The abnormality is due to the presence of hemorrhage or infarcted cerebral tissue Failure of the scan to demonstrate the aneurysm was documented also in the normal studies of three patients whose third nerve palsy was the only symptom of an internal carotid artery aneurysm Presumably little or no cerebral damage had occurred The use of the radioisotopic scan in the evaluation of patients with seizures is empasized In two instances positive studies led to further diagnostic procedures and appropriate therapy

We have been confronted occasionally by a patient with multiple aneurysms but no arteriographic evidence to indicate which aneurysm had bled Clinical examinations either were inconclusive or pointed to an aneurysm subsequently found not to be the source of hemorrhage Since most abnormal arsenic scans correctly localize the area adjacent to or in the territory of the vessel harboring the ruptured aneurysm it may be possible to utilize this diagnostic procedure in determining which of the aneurysms has ruptured

In patients with intracerebral hemorrhage scanning with ^{74}As is a valu

Table 3

Radioisotopic scans in patients with spontaneous intracerebral hemorrhage

Deficit at scan	^{74}As		^{64}Cu		Total
	Abnormal	Normal	Abnormal	Normal	
Severe	9	3	1	3	16
Moderate	2	1	2	3	8
Mild	1	1	1	1	4
Total	12	5	4	7	28

Table 4

Radioisotopic scans in patients with permanent neurologic deficits following cerebral infarction

Deficit at scan	^{74}As		^{64}Cu		Total
	Abnormal	Normal	Abnormal	Normal	
Severe	11	1	3	5	20
Moderate	23	13	3	9	48
Mild	10	2	3	3	18
Total	44	16	9	17	86

unbalance (AGG) associated with a more diffuse increase in concentration on the coincidence scan. This finding was apparent in a number of the abnormal studies.

In patients with arteriographic evidence of carotid occlusive disease, 10 of 11 arsenic scans were abnormal. These scans usually showed a larger, more diffuse area of abnormality than did those of patients with intracranial occlusive disease. All 4 patients studied with copper had normal studies.

Analysis of the correlation between onset of deficit and time of scan revealed a high percentage of abnormal studies during the first four weeks after onset, followed by a gradual decrease in the percentage of abnormal studies.

Twenty-five patients had a neurologic deficit at the time of the scan, but there was recovery of function over subsequent weeks or months. Within this group there were 19 patients with a mild deficit. Only 5 had abnormal scans. In contrast, in the group of patients whose mild deficit persisted 10 of 12 scans were abnormal.

Transient ischemic attacks. In this group of 22 patients, 15 had symptoms in the carotid territory and 7 symptoms in the vertebral basilar system. In each group there were only two 'probably abnormal' studies.

SUMMARY

Scanning with ^{74}As and ^{64}Cu has been evaluated in cerebral vascular disease A high percenta e of ruptured intracranial aneurysms have increased concentration The aneurysm itself is not demonstrated but chang s in adjacent cerebral tissue are seen Scans of arterio-venous malformations also appear abnormal All hypertensive intracranial hemorrhages were lo alized with ^{74}As during the s cond and third weeks after onset. Permanent neurologic deficit asso iated with cerebral infarction due to thrombotic o clusion usually produces an abnormal arsenic scan durin g he first 4 weeks after onset Transient ischemic attacks or *temporary neurologic* deficits usually yield normal scans All scans of embolism were negative The Cu chelate sho ed a much lower percentage of abnormal iso opic concentrations than arsenate

ZUSAMMENFASSUNG

Scanning mit ^{74}As und Cu wurde bei zerebralen Gefasserkrankungen angewendet Ein hoher Prozentsatz von rupturierten intrakraniell n Aneurysmen zeigen erhohte Konzentration *Das Aneurysma selbst wird nicht dargestellt jedoch konnen* die Veranderungen des umgeben den Gewebes gesehen werden Scans von arteriovenosen Missbildungen erscheinen auch normal Alle hypertensiven intrakraniellen *Blutungen wurden mit* ^{74}*As in der zweiten und* dritten Krankheitswoche lokalisiert Dauernder neurologischer Ausfall ergibt beim trombotisch bedingten zerebralen Infarkt in den ersten vier Krankheitswochen gewohnlicherweise ein abnormes Arsen Scan Vorubergehende ischamische Attacken und temporare neurologische Ausfälle ergeben gewohnlich normale Scans Alle Scans bei Embolie waren negativ Scanning bei Verwendung von ^{64}Cu ergab einen viel geringeren Prozentsatz von abnormaler Isotopen konzentration als bei Anwendung von As

RESUMÉ

Les auteurs ont étudie la scintigraphie par ^{74}As et ^{64}Cu dans les affections vasculaires cérebrales Un grand nombre des anévrismes intracraniens rompus presentent une concentration augmentée L anévrisme lui même n est pas mis en évidence mais on voit les lésions du tissu cérébral adjacent Les scintigraphies de malformations artério-veineuses sont elles aussi normales Toutes les hémorragies intracraniennes donnant une hypertension intracranienne ont été lo alisées par ^{74}As dans les deux eme et troisieme sema nes après leur début Le déficit neurologique permanent du ramollissement cérébral par occlusion thrombotique se traduit habituellement par une scintigraphie à l arsenic anormale pendant les quatre premières s maines apres le début Les accidents ischémiques transitoires ou les deficits neurolo iques passagers donnent habituellement des scintigrammes normaux Tous les s intigrammes d embolies ont été négatifs Le chélate de ^{64}Cu a eu une proportion de con centrations isotopiques anormales bien moindre que l arsénite

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able diagnostic aid in localizing the site of the lesion Twelve of 17 arsenic scans were abnormal while only 4 of 11 copper studies had an increased concentration In no specific area does hemorrhage appear to be more likely to produce an abnormal scan

FEINDEL and co workers (15) concluded in one case of intracerebral hemorrhage that 'uptake was mainly on the basis of the recent bleeding or the edema of the adjacent brain tissue about the clot' In our study of two patients, one given ^{74}As and ^{64}Cu and the other ^{64}Cu, concentration of the radioisotopes in the cerebral tissue adjacent to the clot was several times that found within the hematoma itself

Another fact to be noted is that all copper and arsenic scans were abnormal during the second and third weeks after hypertensive intracerebral hemorrhage During the first week there was a high percentage of normal studies, indicating that the alteration of the tissue surrounding the hematoma may induce further changes in the surrounding tissue and result in an increased concentration of isotope This could prove to be an important point in assessing the time of surgical therapy in these lesions Removal of the hematoma within the first week after onset of symptoms may be indicated since its continued presence appears to alter the surrounding tissue

Over 90 % of the patients with a severe, persistent neurologic deficit due to thrombotic infarction will have an abnormal arsenic scan ^{64}Cu chelates localize poorly in these regions Even when the neurologic deficit is mild we find that 83 % of the scans are abnormal if the deficit is going to persist, in contrast to the 26 % abnormality in cases where the mild neurologic deficit is only temporary On the basis of this data, it might be possible to make some assessment of the prognosis from the radioisotopic scan When a neurologic deficit is present and an abnormal arsenic scan is in good agreement with the suspected area of involvement, the deficit will be likely to persist *On the* other hand, if the scan is normal there is a better chance of full recovery If a copper scan is abnormal with any degree of deficit, the deficit probably will be permanent In patients with carotid occlusive disease when carotid surgery is being considered, the radioisotopic brain scan could be of assistance in indicating the extent of cerebral injury If one finds an abnormal scan in a patient thought to have cerebral embolism or transient ischemic attacks, care should be exercised in following the patient closely for development of tumor

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Origine des signaux dans les techniques ambulatoires Les signaux recueillis au cours de ces explorations sont émis par des générateurs différents

Les figures de l E E G proviennent du *cortex hémisphérique* au contact de la voute et non de la tumeur, l oedeme cérébral joue le role majeur dans l apparition des ondes lentes

Les molécules radioactives pénetrent plus dans le tissu tumoral que dans le tissu cérébral sain le rayonnement gamma des molécules radioactives provient essentiellement du tissu d oedème, c est en tout cas par l intermédiaire des vaisseaux que les émetteurs gamma pénetrent dans ce que d une maniere imprécise nous appelons la lésion tumorale

L écho median ultra sonore se réfléchit sur des interfaces encore discutées, il n y a pas un echo, mais des échos l observateur doit identifier l écho reflêchi par une formation anatomique repoussée de l autre coté de la ligne médiane septum pellucidum, citerne interhemisphérique 3e ventricule *épiphyse? difficile a dire*[1]

Si les générateurs des signaux sont différents en E E G G E G et Echographie un facteur leur est pourtant commun l oedeme, qui entoure la tumeur favorise les ondes lentes la fixation sélective de l émetteur gamma et le passage de l hémisphere dans l hemicrane oppose

Applications cliniques

Nous allons envisager l emploi de ces techniques ambulatoires de plusieurs points de vue 1) diagnostic positif de tumeur cérébrale 2) diagnostic étiologique — nature de la lésion occupant de l espace et 3) diagnostic precoce

La premiere question porte sur l existence d une formation occupant de la place Sur 110 lesions expansives (dont 98 vérifiées a l intervention) l E E G est franchement positif 100 fois le G E G est franchement positif 99 fois, et l Echo est franchement positif 80 fois Le fond d oeil ne montre une stase papillaire que 47 fois Dix fois l E E G se révele négatif ou à la limite du normal, comme suit

		G E G	Echo M
1	Ment g ome to t orb tal	+	0
2	Mén ng n e en plaque	+	0
3	Mén ng on e pariet l	+	0
4	C nul me crane	+	0
5	Lymphosarcome fosse temp	+	6 mm
6	Tuberculome par sagittal	+	15 mm
7	Abc s p r ét l	+	0
8	Cl blasto e	+	35
9	Cl ome pédo cul e	—	11
10	Recid s	+	0

HOPITAL DE LA PITIE, PARIS, FRANCE

EXPLORATIONS TECHNIQUES AMBULATOIRES DANS LE DIAGNOSTIC DES TUMEURS CEREBRALES HEMISPHERIQUES

par

TH. PLANIOL, J. METZGER, M. DAVID et H. FISCHGOLD

Le diagnostic *pré-opératoire* d'une tumeur cérébrale hémisphérique implique des examens de contraste iodés ou gazeux. Le diagnostic positif et le *diagnostic étiologique* exprimés en termes de probabilité, ne suffisent plus, le neurochirurgien a besoin de connaître le siège exact de la néoformation, son volume et ses rapports avec les structures intracraniennes.

Pour intervenir ou s'abstenir, il demande des informations aussi précises que possible sur l'histologie de la néoformation.

Enfin on évitera l'inflation des examens de contraste, entachés de quelques risques et pas mal de désagréments, en pratiquant les trois techniques ambulatoires: 1) L'E.E.G., 2) *les radio-isotopes*, gammaencéphalographie ou scanning, et 3) l'échographie de la ligne médiane par ultrasons A. Restent la thermographie et la pallencéphalographie dont *on nous parlera ici*, et la rhéoencéphalographie qui décourage beaucoup d'entre nous parce qu'on en a parlé trop tôt!

Enfin, la tomographie à ultrasons B dont vous avez aux Etats-Unis une première expérience pleine de promesses.

PLANIOL et METZGER ont comparé les conclusions pré opératoires du G E G et de l angiographie dans 275 cas de T C H il résulte de cette confrontation que sur 225 diagnostics de nature, le G E G s est montré 43 fois erroné sur 157 diagnostics étiologiques, l angiographie s est montrée erronée 17 fois

Des informations sur la nature et l histologie des néoformations deviennent donc de plus en plus significatives si on ajoute a la radiographie standard le G E G sans oublier un bon interrogatoire et l examen clinique

Le nombre des T C H devant lesquelles le neurochirurgien reste hésitant avant l arteriographie tend donc a baisser si on utilise les explorations ambulatoires et complementaires énumérees

La troisième question est si on peut par les techniques enumerees reconnaitre une tumeur cerebrale au début Il devient évident que nous sommes actuellement en état de faire le diagnostic de T C H par l E E G , le G E G et l Echo avant l apparition de la stase papillaire Ceci marque un grand progres realisé au cours des 20 dernieres années et prouve que le diagnostic des tumeurs hemisphérique se fait déjà a une phase beaucoup plus precoce qu il y a 10 ou 15 ans

Un diagnostic précoce devient possible aussi du fait que la sémiologie neurologique s est raffinee et l expérience des praticiens élargie ils pensent a une tumeur plus tot qu autrefois et s inquiètent devant toute épilepsie tardive et devant tout deficit neurologique psychique ou sensoriel

Sur les trois techniques laquelle est la plus précoce ou la plus tardive?

E E G Sur une serie de 65 néoformations, BUISSON FEREY a noté que les abces les hématomes intra cérébraux et les glioblastomes s accompagnent d un E E G evocateur avant la fin du ler mois d évolution clinique, plus le processus evolue rapidement (meme benin comme l abces) plus les anomalies electriques sont precoces

Les méningiomes peuvent montrer un tracé non évocateur ou normal apres une évolution de mois ou d annees (voir le Tableau)

Le G E G fournit par contre des signes plus précoces que E E G dans les méningiomes de la convexité plus de 80 % *montrent un foyer* G E G *net* au cours de la premiere année d évolution clinique

Mais la nature de la lésion imprime nettement son cachet ainsi 40 % des *astrocytomes resteront* jusqu a la fin négatifs au G E G

Si l on reprend les 110 T C H *dont nous avons déja parlé on trouve E E G* négatifs 10 G E G négatifs 11 Echo negatifs 30, Fond d oeil négatifs 63

Du point de vue du diagnostic precoce E E G et G E G paraissent d une *sensibilité équivalente* et l Echo franchement plus tardif, le fond d'œil reste

Neuf fois la négativité de l'E.L.G. se trouvait compensée par un G.E.G. positif et deux fois par un déplacement très significatif de la ligne médiane; les cinq premiers cas appartiennent aux tumeurs lentement évolutives ou propres du crâne, l'E.L.G. négatif ne constitue pas une surprise et la radiographie standard du crâne reste pour ces cas l'examen ambulatoire de choix.

Onze fois le G.E.G. se montre négatif.

		E.L.G.	Echo M
1	Astrocytome temporal	Δ	15
2	Astrocytome temporal	Δ	25
3	Astrocytome temporal	Δ	26
4	Oligodendrogliome	+	6
5	Gliome kystique frontal	+	0
6	Métastase isolée	Δ	0
7	Métastase thalamique pédonc.	Δ	6
8	Tumeur thalamique	+	16
9	Tumeur thalame pédonculaire	+	11
10	Abcès temporal	+	3
11	Hématome intra cérébral	+	2

Δ = ondes delta polymorphes en foyer très évocatrices d'une lésion localisée.

Trois fois pour des astrocytomes — notion bien connue, les trois fois l'E.E.G. évocateur (Δ delta) et des déplacements énormes de l'Echo M. redressent le diagnostic; trois fois l'E.L.G. et de gros déplacements corrigent le G.E.G. négatif dans les tumeurs thalamiques ou pédonculaires profondes; quatre fois l'Echo M se montre normal ou son déplacement peu significatif avec un E.E.G. positif; sur ces quatre derniers cas nous ne notons que deux tumeurs.

L'Echo négatif 30 fois sur 110, apparaît comme le procédé le moins fidèle et de ce fait comme une exploration en retard sur l'E.E.G. et le G.E.G., mais sur 30 résultats négatifs, 27 proviennent de tumeurs paramédianes ou bilatérales (métastases). La faux du cerveau empêche certaines circonvolutions de se déplacer dans l'hémicrâne opposé, mais ne les empêche pas d'émettre des ondes delta polymorphe ou de fixer les radioisotopes plus que le cerveau sain.

La seconde question est la nature de la néoformation. L'E.E.G. manque de spécificité mais réfléchit l'évolution rapide ou lente de la néoformation: très anormal pour l'abcès, il peut rester normal pour le méningiome.

Le G.E.G. tel que nous l'utilisons à la *Pitié* indique souvent la nature du processus expansif. Dans la technique de Madame PLANIOL, l'examen répété pendant 2 ou 3 jours consécutifs révèle un foyer d'hyperactivité gamma: 1) immédiat dans les angiomes, 2) précoce dans les méningiomes, 3) tardif dans les glioblastomes, et 4) très tardif dans les métastases.

PLANIOL et METZGER ont comparé les conclusions pré opératoires du G E G et de l angiographie dans 275 cas de T C H il résulte de cette confrontation que sur 225 diagnostics de *nature* le G E G s est montré 43 fois erroné sur 157 diagnostics étiologiques l angiographie s est montrée erronée 17 fois

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Le nombre des T C H devant lesquelles le neurochirurgien reste hésitant avant l artériographie tend donc a baisser si on utilise les explorations ambulatoires et complémentaires énumérées

La troisième question est si on peut par les techniques enumerees reconnaître une tumeur cerebrale au debut Il devient évident que nous sommes actuellement en état de faire le diagnostic de T C H par l E E C le G E G et l Echo avant l apparition de la stase papillaire Ceci marque un grand progrès realisé au cours des 20 dernieres années et prouve que le diagnostic des tumeurs hemisphérique se fait déja a une phase beaucoup plus precoce qu il y a 10 ou 15 ans

Un diagnostic précoce devient possible aussi du fait que la semiologie neurologique s est raffinée et l expérience des praticiens elargie ils pensent a une tumeur plus tot qu autrefois et s inquietent devant toute épilepsie tardive et devant tout déficit neurologique psychique ou sensoriel

Sur les trois techniques laquelle est la plus precoce ou la plus tardive ?

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Les méningiomes peuvent montrer un tracé non évocateur ou normal apres une évolution de mois ou d années (voir le Tableau)

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Mais la nature de la lésion imprime nettement son cachet ainsi 40 % des astrocytomes resteront jusqu a la fin négatifs au G E G

Si l on reprend les 110 T C H dont nous avons déja parlé on trouve E E G négatifs 10 G E G *négatifs* 11 Echo negatifs 30 Fond d oeil négatifs 63

Du point de vue du diagnostic précoce E E G et G E G paraissent d une sensibilité équivalente et l Echo franchement plus tardif le fond d œil reste

Neuf fois la négativité de l'E.E.G. se trouvait compensée par un G.E.G. positif et deux fois par un déplacement très significatif de la ligne médiane, les cinq premiers cas appartiennent aux tumeurs lentement évolutives ou propres du crâne, l'E.E.G. négatif ne constitue pas une surprise et la radiographie standard du crâne reste pour ces cas l'examen ambulatoire de choix.

Onze fois le G.E.G. se montre négatif.

		E.E.G.	Echo M
1	Astrocytome temporal	Δ	15
2	Astrocytome temporal	Δ	25
3	Astrocytome temporal	Δ	26
4	Oligodendrogliome	+	6
5	Gliome kystique frontal	+	0
6	Métastase isolée	Δ	0
7	Métastase thalamique pédonc.	Δ	6
8	Tumeur thalamique	+	16
9	Tumeur thalamo-pédonculaire	+	11
10	Abcès temporal	+	3
11	Hématome intra-cérébral	+	2

Δ = ondes delta polymorphes en foyer très évocatrices d'une lésion localisée.

Trois fois pour des astrocytomes — notion bien connue, les trois fois l'E.E.G. évocateur (Δ delta) et des déplacements énormes de l'Echo M. redressent le diagnostic, trois fois l'E.E.G. et de gros déplacements corrigent le G.E.G. négatif dans les tumeurs thalamiques ou pédonculaires profondes, quatre fois l'Echo M. se montre normal ou son déplacement peu significatif avec un E.E.G. positif, sur ces quatre derniers cas nous ne notons que deux tumeurs.

L'Echo négatif 30 fois sur 110, apparaît comme le procédé le moins fidèle et de ce fait comme une exploration en retard sur l'E.E.G. et le G.E.G., mais sur 30 résultats négatifs, 27 proviennent de tumeurs para-médianes ou bilatérales (métastases). La faux du cerveau empêche certaines circonvolutions de se déplacer dans l'hémicrâne opposé, mais ne les empêche pas d'émettre des ondes delta polymorphes ou de fixer les radioisotopes plus que le cerveau sain.

La seconde question est la nature de la néoformation. L'E.E.G. manque de spécificité mais réfléchit l'évolution rapide ou lente de la néoformation : très anormal pour l'abcès, il peut rester normal pour le méningiome.

Le G.E.G. tel que nous l'utilisons à la *Pitié* indique souvent la nature du processus expansif. Dans la technique de Madame PLANIOL, l'examen répété pendant 2 ou 3 jours consécutifs révèle un foyer d'hyperactivité gamma : 1) immédiat dans les angiomes, 2) précoce dans les méningiomes, 3) tardif dans les glioblastomes, et 4) très tardif dans les métastases.

PLANIOL et METZGER ont comparé les conclusions pré opératoires du G E G et de l angiographie dans 275 cas de T C H il resulte de cette confrontation que sur 225 diagnostics de nature le G E G s est montre 43 fois erroné sur 157 diagnostics étiologiques l angiographie s est montrée erronée 17 fois

Des informations sur la nature et l histologie des néoformations deviennent donc de plus en plus significatives si on ajoute a la radiographie standard le G E G sans oublier un bon interrogatoire et l examen clinique

Le nombre des T C H devant lesquelles le neurochirurgien reste hésitant avant l artériographie tend donc a baisser si on utilise les explorations ambulatoires et complementaires énumérées

La troisieme question est si on peut par les techniques enumeeers reconnaitre une tumeur cerebrale au debut Il devient évident que nous sommes actuellement en état de faire le diagnostic de T C H par l E E G le G E G et l Echo avant l apparition de la stase papillaire Ceci marque un grand progres realise au cours des 20 dernieres années et prouve que le diagnostic des tumeurs hémisphérique se fait deja a une phase beaucoup plus précoce qu il y a 10 ou 15 ans

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Tableau

On considère précocc l'enregistrement pratiqué après le début clinique au cours des 14 premiers jours pour les abcès du premier mois pour l'hématome intracérébral et le glioblastome des six premiers mois pour l'astrocytome de la première année pour l méningiome S P = Stas papillaire

65	34	Γ Exp au debut	Sans S P	31 avec S P								
				0	I		II		III		IV	
8	5	Abces	< 14j						2	1	1	4
7	3	Hématome I Cer	< 1m						2	3	2	
19	9	Glioblast	< 1m	1			3	2	4	1	3	5
10	6	Astrocyt	< 6m			1	1	1	2	1	1	3
9	6	Mening	< 1an		2	1	1	2		2		1
12	5	Metastases		1		1		1	3	1	4	1

normal dans plus de la moitié des 110 tumeurs au moment ou les autres explorations physiques ambulatoires sont déjà positives, la meme conclusion se dégage des études de Toyvis

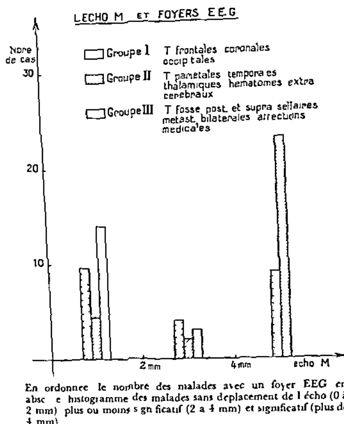
Mais sur 110 tumeurs examinées a une periode evolutive donnee, ce ne sont pas les memes malades qui ont un E E G et un G E G negatif, ou un G E G et un Echo négatif, fait significatif, sur cette série de 110 sujets il n'y en a eu aucun avec E E G, G E G et Echo négatifs a la fois

E E G et G E G attestent en pourcentage la meme précocité diagnostique sur les 110 tumeurs, mais en considérant les trois explorations physiques a la lumiere des cas individuels le type histologique joue un role fondamental, nous venons de voir que le méningiome, compatible longtemps avec un tracé E E G normal, se révele des le début par un foyer gamma caracteristique, tandis que l astrocytome assez rapidement positif en E E G, peut echapper au G E G jusqu a la fin de l évolution enfin le glioblastome meme negatif en E E G et G E G au moment des premieres manifestations cliniques accuse un virage positif si on répete l examen apres quelques semaines les signes cliniques accusant aussi une progression rapide

En pratiquant donc a titre systématique, en plus de la radiographie sans substance de contraste et de l examen oculaire, les trois techniques physiques citées, nous disposons d une grande probabilité pour faire un diagnostic précoce avant de le préciser par les substances de contraste

Pour conclure nous allons revenir sur l échographie médiane, c'est la technique la plus récente qui, malgre sa simplicité apparente, pose le plus de problemes et souleve le plus de difficultés

Difficultes qui proviennent du fait que la recherche de l Echo M se termine



En ordonnée le nombre des malades avec un foyer EEG en abscisse histogramme des malades sans déplacement de l'écho (0 à 2 mm), plus ou moins significatif (2 à 4 mm) et significatif (plus de 4 mm).

dans quelques minutes le film polaroïde objective un écho — dégagé parmi beaucoup d'autres avec la sonde appliquée sur un point choisi assez arbitrairement sur le crâne, écho obtenu sous un angle qu'on suppose perpendiculaire à l'interface explorée.

Mais cette interface *anatomiquement inconnue (car c'est cette interface qu'on cherche)* varie avec le déplacement et l'angulation de la sonde, l'Echo M reste donc malgré le film polaroïde l'exploration complémentaire la plus subjective.

Subjectivisme qui ne trouve sa correction que dans l'habileté et l'expérience clinique de l'observateur.

MIKOL met dans un histogramme (voir diagramme) les résultats de l'Echo médian dans 69 cas avec foyers E.E.G. évocateurs.

Sur 23 tumeurs frontales, coronales ou occipitales seulement 9 ont déplacé l'Echo de 4 mm ou plus, 10 ne l'ont pas déplacé du tout.

Par contre sur 29 tumeurs pariétales, temporales, thalamiques ou hématomes extracérébraux, 25 ont déplacé l'Echo médian d'une manière très significative.

Le facteur qui intervient dans la positivité de l'Echo paraît plutôt anatomique et mécanique, l'Echo a toute chance de constituer un signe de diagnostic précoce pour les tumeurs (temporales, thalamiques etc.) non gênées dans leur expansion par la faux du cerveau.

Mais quand l'Echo, à coté du G.E.G., redresse la conclusion d'un E.E.G. normal pour certaines néoformations à évolution lente comme le méningiome, et quand il compense un G.E.G. normal pour certains astrocytomes ou tumeurs profondes, nous le considérons comme bien venu, malgré son subjectivisme et ses limitations.

Conclusion

Tout sujet âgé de plus de 25 ans, accusant des crises convulsives, des céphalées ou des signes déficitaires d'apparition récente, doit être exploré par des techniques ambulatoires: radio du crâne, fond d'œil, E.E.G., G.E.G. et Echo M.

L'intégration de ces résultats à la clinique, évite ou justifie les examens de contraste auxquels on demande la véritable radio-anatomie lésionnelle.

Du fait de l'utilisation de l'E.E.G., du G.E.G. et de l'Echo, le fond d'œil ne fournit des résultats positifs que dans un pourcentage de plus en plus réduit de cas.

Les résultats de ces trois examens ambulatoires, se laissent ainsi formuler:

E.E.G. G.E.G. Echo	+ + +	Tumeur pratiquement certaine: les examens de contraste s'imposent.
E.E.G. G.E.G. Echo	— — —	Tumeur peu probable: attendre et répéter les examens ambulatoires surtout *EEG & ECHO* en fonction de l'évolution clinique.
E.E.G. G.E.G. Echo	— + +	Méningiomes, oligodendrogliomes, tumeurs propres du crâne: angiographie de la carotide interne et externe.
E.E.G. G.E.G. Echo	+ + —	T. coronale, occipitale, paramédianes ou métastases bilatérales: examens de contraste.
E.E.G. G.E.G. Echo	+ — +	Astrocytomes, tumeurs profondes de petit volume, médianes: examens de contraste.

Pour les trois dernières éventualités, seuls les examens de contraste vont lever le doute, G.E.G. et E.E.G. ayant fourni des indications topographiques assez valables.

Les techniques physiques d examen ambulatoire exploitent des particularités lesionnelles et des signaux de provenance différentes d ou leur caractere complementaire

La probabilité pour que les 3 explorations physiques ambulatoires restent négatives sur le meme malade atteint d une néoformation hemisphérique parait de ce fait réduite

Si la neoformation evolue rapidement (glioblastome) ou infiltre le parenchyme cérebral (astrocytome) l E E G devient positif d une maniere assez precoce

Le G E G s avere positif des le debut clinique pour certains types histologique comme le meningiome mais peut rester négatif jusqu a la fin pour d autres types comme l astrocytome il est precoce dans le glioblastome

Enfin les facteurs mecaniques qui agissent sur l écho médian lui impriment un caractere diagnostique plutot tardif meme si la topographie de la néoformation parait favoriser les déplacements en masse du cerveau

RÉSUMÉ

Les techniques ambulatoires de recherche des tumeurs cerébrales en particulier l E E G le G E G et l echo M permettent d établir les indications des examens radiographiques avec moyen de contraste Si ces 3 techniques sont positives la tumeur cérebrale est pratiquement certaine et les examens avec moyen de contraste sont indiques Si elles sont négatives la tumeur est peu probable Quand leurs resultats sont discordants elles renseignent cependant souvent sur le siege et la nature de la tumeur et les examens avec moyen de contraste préciseront le diagnostic

SUMMARY

Alternating techniques for the investigation of cerebral tumours especially E E G G E G and the M echo make it possible to establish indications for radiographic examinations with contrast media If all three techniques give positive results the presence of a tumour is almost certain and examination with contrast media is indicated If they are all negative it is not likely that a tumour is present When their results are conflicting they can nevertheless often give information regarding the site and nature of the tumour and the examination ith contrast medium will help to establish the diagnosis

ZUSAMMENFASSUNG

Verschiedene Techniken fur ambulatorische Untersuchungen von Gehirntumoren besonders E E G G E G und das M Echo machen es moglich Indikationen fur Kontrastmittel untersuchungen aufzustellen Falls alle drei Techniken positive Resultate geben ist das Vorkommen ines Tumors fast sicher und eine Untersuchung mit Kontrastmittel ist empfehlenswert Falls alle drei negativ sind ist es nicht anzunehmen dass ein Tumor vorhanden ist Wenn ihre Resultate widersprechend sind konnen sie trotzdem oft Informationen uber den Platz und die Natur des Tumors geben und Untersuchungen mit Kontrastmittel helfen eine Diagnose aufzustellen

Par contre sur 29 tumeurs pariétales, temporales, thalamiques ou hématomes extracérébraux, 25 ont déplacé l'Echo médian d'une manière très significative.

Le facteur qui intervient dans la positivité de l'Echo paraît plutôt anatomique et mécanique; l'Echo a toute chance de constituer un signe de diagnostic précoce pour les tumeurs (temporales, thalamiques etc.) non gênées dans leur expansion par la faux du cerveau.

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by

KENJI TANAKA and KAZUFUMI ITO

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Technical equipment An ultrasonic apparatus Model SSD 2 developed by the Japan Radio Co of Tokyo has been used in this work The echoes are displayed on the Braun tube by A scope indication

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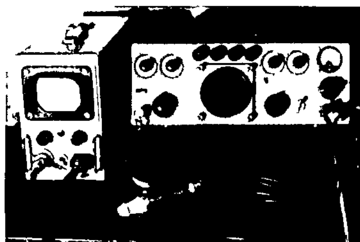


Fig 1 Ultrasonic diagnosing apparatus (right) and its monitor (left)

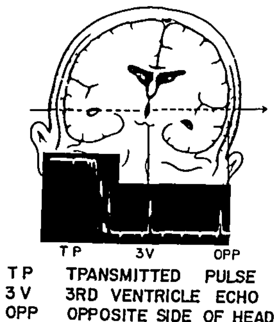
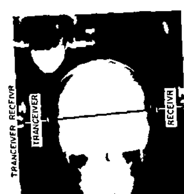
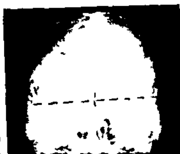


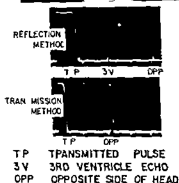
Fig 2 Normal pattern of intracranial echo at the temporal region

Examination technique and findings

For examination through the scalp, liquid paraffin is applied to the surfaces of the transducer and scalp as a coupling medium The transducer is held by hand and it is desirable to shave off the hair in order to make a good contact Standard examination is performed through the temporal and frontal regions of the head







T P TPANSMITTED PULSE
3 V 3RD VENTRICLE ECHO
OPP OPPOSITE SIDE OF HEAD

Fig 3 Verificat on of third entr cle echo The encephalogram shows the direct on of the ultra onic beam

Midline echo The examination through the temporal region is easier because the temporal bone is thin When the transducer is placed just in front of and over the ear the echo originating from the third ventricle wall is detected as a midline pulsating echo These pulsations are synchronous with the heart beat (Fig 2) When the transducer is applied in this position ultrasound does not pass the falx cerebri or pineal gland

Experimentally using a brain specimen in a water tank a thin steel blade was inserted into the third ventricle and the midline echo was then detected with greater ease

Furthermore the direction of the ultrasonic beam is measured using reflec tion and transmission methods The third ventricle echo being at the midline is best obtained when the transducer is applied just above and ahead of the external ear using the reflection method The direction of the ultrasound beam was confirmed by radiography applying the transmission from the same point On this occasion encephalography revealed that the ultrasonic beam of the transducer passes through the third ventricle (Fig 3)

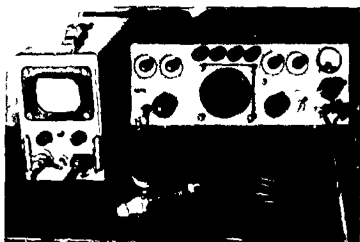


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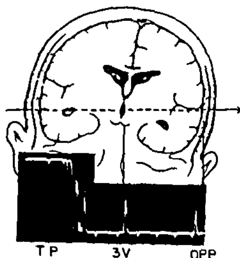


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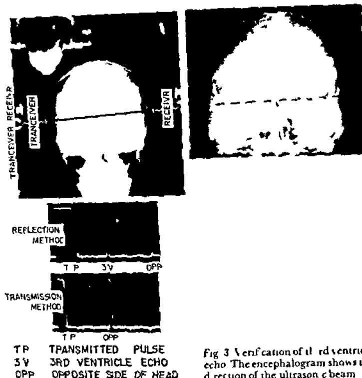


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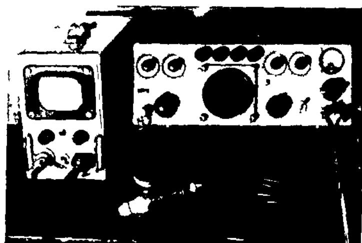


Fig 1 Ultrasonic diagnosing apparatus (right) and its monitor (left)

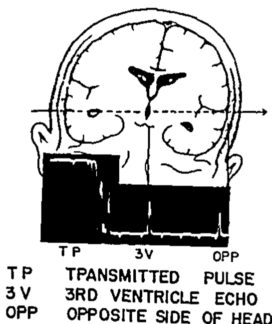
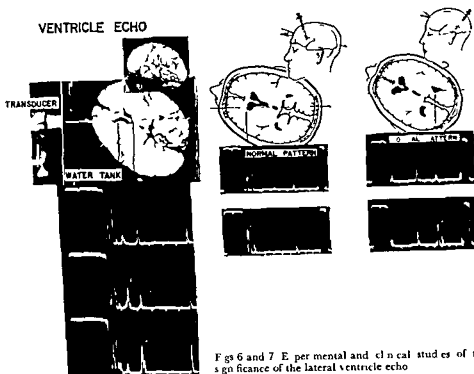


Fig 2 Normal pattern of intracranial echo at the temporal region

Examination technique and findings

For examination through the scalp liquid paraffin is applied to the surfaces of the transducer and scalp as a coupling medium The transducer is held by hand, and it is desirable to shave off the hair in order to make a good contact Standard examination is performed through the temporal and frontal regions of the head



Figs 6 and 7 Experimental and clinical studies of the significance of the lateral ventricle echo

the frontal region With regard to the question of structures responsible for the echoes registered the writers have carried out the following experiments to clarify this problem

1 By using a human brain in a water tank and pulsed ultrasound through the frontal region to the occipital area a distinct reflection wave was detected when a rubber tube (3 mm in diameter) was inserted into the anterior horn of the lateral ventricle (Fig 6)

2 Clinically patients with burr holes for ventriculography in the frontal and occipital region were examined When the rubber tube was inserted into the anterior horn and posterior horn by ventricular puncture the pulsating echoes were detected *more distinctly* from the examination through the frontal region (Fig 7)

Acoustic impedance of normal brain and tumor tissue

It has been a question whether the difference of the acoustic impedance between brain tumor tissue and normal brain tissue is too small to cause sufficient reflection of the ultrasonic wave

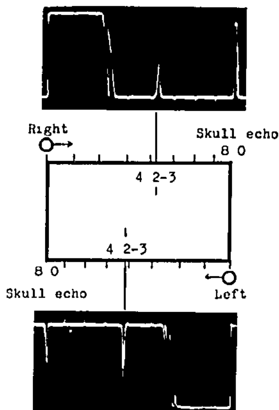


Fig 4

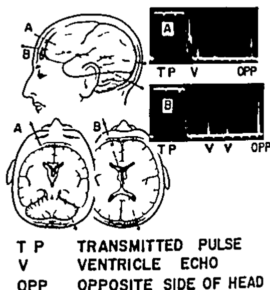


Fig 5

Figs 4 and 5 Normal patterns of third ventricle echo and of intracranial echoes in the frontal region

The third ventricle echo is detected at 4 2—4 3 with the time marker (dividing by 8) set to the beginning of the final echo If the ventricle is deviated by more than 0 2 mark, we can be convinced of a shift of this ventricle (Fig 4)

As already reported (TANAKA 1962, TANAKA et coll 1961, 1962, 1963), many echoes which pulsate synchronously with the heart beat are observed from within the brain A great part of these echoes are probably due to the ventricle walls Continuous records of these pulsating echoes, especially the third ventricle echo, were made on the cathode ray screen for the analysis of these phenomena As the method of recording, both time position indication and continuous record of echo height were used In hydrocephalic patients the pulsations are approximately 180 out of phase with each other

The lateral ventricles For this examination the beam was passed from the frontal region to the occipital area, with a finding of some pulsating echoes from within the brain (Fig 5) In some cases we found pulsating echoes through



F g 8 Normal pattern of ntracran al echo midl ne locator at the temporal reg on

respectively in fresh specimens From the results of these experiments, the acoustic impedance of brain tumor tissue is greater than that of normal tissue Thus it is theoretically possible that the border between brain tissue and tumor tissue will cause a reflection (Table 1)

Furthermore the tumor echo pattern is complicated and the ultrasonic attenuation is different In addition to the diagnosis of brain tumors by echo

Table 4

Results of ultrasonic diagnosis of brain tumor

Loc l t n of tumor	Number of cases examined	Number of co rectly diagnosed ca es
Cerebral h mispheres	55	53
Ch asm l eg on	18	14
Rostral bra n stem	8	3
Caudal br n tem	5	0
Ce eb llum	11	9
Fourth vent cle	1	0
Cerebello-pont ne ngle	13	1
Total	111	80

Table 1

Acoustic impedance of normal brain specimen and brain tumor tissues

	Velocity, c cm/sec × 10⁵	Density ρ g/cc	Acoustic impedance ρc × 10
Cerebrum	1 46	1 036	0 151
Astrocytoma (grade II)	1 66	1 034	0 171
Retinoblastoma	1 60	1 046	0 167
Meningioma	1 64	1 050	0 172
Meningioma (fibroblastic)	1 64	1 040	0 171
Meningioma (meningotheliomatous)	1 66	1 048	0 173
Metastatic cancer (adenocarcinoma)	1 59	1 058	0 168

Table 2

Ultrasonic attenuation on brain tumor compared with normal brain

	5 megacycle	10 megacycle
Meningioma	+ 2 75	+ 5 15
Neurinoma	— 2 5	— 4 5
Chromophobe adenoma	— 1 0	— 1 53
Astrocytoma	0	0
Glioma (unclassified)	— 1 75	— 5 0
Medulloblastoma	— 1 75	— 6 1
	db/cm	db/cm

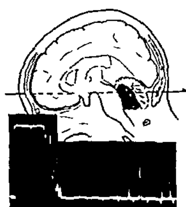
Table 3

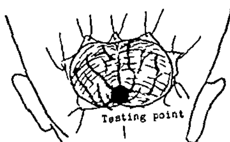
Ultrasonoechograms checked by radiograms on 92 patients

Ultrasonoechography	Checked by neuroradiology	
Displacement of third ventricle	Median structures shifted	53 cases
echo 56 cases	No shift of median structures	3 cases
No displacement of third ventricle	Median structures shifted	0 cases
36 cases	No shift of median structures	36 cases

The acoustic impedance of a substance is defined as the product of the density of the substance and the velocity of sound in it The velocity of sound from fresh specimens was measured with a c clamp transducer

The acoustic impedances for normal brain tissue, meningioma and glioma were found to be 1 51 × 10^5, 1 71—1 73 × 10^5 and 1 67—1 71 × 10^5 g/cm²/sec





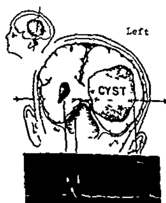
TP T. OPP

TUMOR ECHO

TP TRANSMITTED PULSE
T TUMOUR ECHO
OPP OPPOSITE SIDE OF HEAD

a b

Fig 12 Case of medulloblastoma occupying the fourth ventricle (found and removed at operation) a) Ultrasonic examination through the temporal route The third ventricle echo is large and not displaced At examination through the frontal route abnormal echoes were detected just before the opposite side of the occipital region. b) Surgical exploration At first no abnormality but abnormal echoes were detected on ultrasonic examination of the brain at the posteromedian part at the depth of 4 cm the echoes were irregular and continuous



TP V CE
TP TRANSMITTED PULSE
V VENTRICLE ECHO
CE CYSTIC ECHO

Fig 13 Case of choroid plexus papilloma Ultrasonic examination through the right temporal route The third ventricle echo is displaced to the right At examination through the left temporal route a cystic echo was detected adjacent to the third ventricle echo

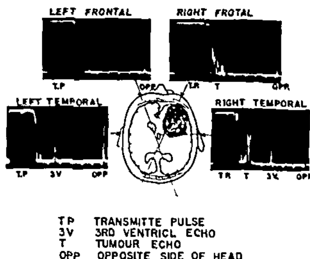


Fig. 9

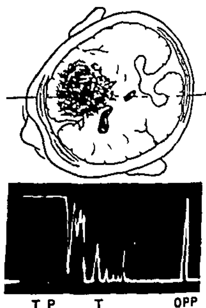
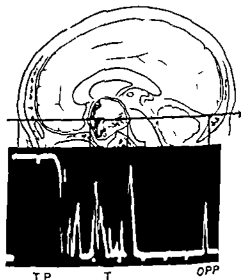


Fig 10

Fig 9 Case of meningioma The ultrasonic examination was performed through the temporal route The third ventricle echo is shifted to the left and the right frontal examination resulted in abnormal irregular echoes adjacent to the transmitted pulse at a depth of 8 cm

Fig 10 Case of glioblastoma Examination through right temporal region showed abnormal irregular echoes adjacent to transmitted pulse at 8 cm depth and through fronto parietal region right side less ultrasonic attenuation and tumor echoes at 6—7 cm depth



T P TRANSMITTED PULSE
T TUMOUR ECHO
OPP OPPOSITE SIDE OF HEAD

Fig 11 Case of craniopharyngioma Examination through the temporal route Third ventricle not displaced Examination through the bilateral frontal route showed abnormal irregular echoes at a depth of 6—7 cm

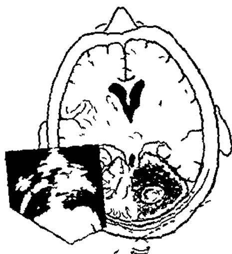


Fig 16 Ultrasonotomogram of a cerebellar tumor showing outside border of cerebellum and tumor echoes including a cystic pattern

Results

Comparison between the third ventricle echo and midline structure displacement The third ventricle as the source of the midline echo ascertained by examination through the above mentioned temporal route was first pointed out by TANAKA et coll (1953 1954)

The use of the ultrasonic echo method to measure the position of the third ventricle will be described in the following

In 89 cases (97 %) of a series of 92 cases confirmed by conventional neuroradiologic investigation the presence or absence of the third ventricle displacement was predicted correctly and in 3 cases (cerebellar tumor, pituitary adenoma and thalamus tumor) the location of the third ventricle was predicted incorrectly by ultrasonic examination (Table 3)

The A scope indication method is useful for clinical diagnosis but sometimes the analysis of the echo patterns is not easy Therefore in order to determine the accurate position of the third ventricle the writers have been engaged in research on a midline locator by means of ultrasound

The midline locator requires slight modification of the standard ultrasonic apparatus, a sensitivity time control circuit is adapted to it and the pass-band of this locator is narrowed The third ventricle echo is detected more readily with this midline locator than with the standard apparatus A barium titanate transducer which is 10 *mm* in diameter and has a frequency of 2 25 megacycles is suitable for detection of the third ventricle through the skull (Fig 8)

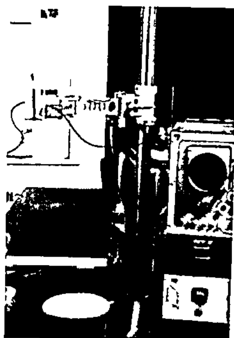
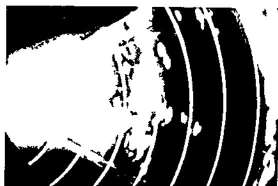




Fig. 14 Apparatus for ultrasonotomography used in the diagnosis of a brain tumor





a b

Fig. 15 Ultrasonotomograms a) Horizontal section of a living human head showing the ventricular pattern The third ventricle is in the midline b) Distinct irregular pattern in a case of temporal meningioma third ventricle shifted

patterns, the observation of the degree of ultrasonic attenuation in the brain is sometimes important Meningiomas show increased attenuation while glioma shows a decreased attenuation in almost all cases Results of ultrasonic attenuation on brain tumor tissue compared with normal brain tissue are shown in Table 2

ZUSAMMENFASSUNG

Es wird die klinische Bedeutung von Ultraschall Diagnostik von *Hirntumoren* mittels der Pulsmethode vorgeführt Es wurde der Standard Ultraschallapparat (Aloka Modell SSD-2 A scope Methode) verwendet und die passenden Frequenzen waren 1—10 Megacyklen Der akustische Widerstand des normalen Gehirns und der von Hirntumoren wird gemessen *Positives Tumorecho* konnte in 80 von 111 Patienten mit Hirntumoren erhalten werden was operativ und autoptisch verifiziert werden konnte Ein Mittellinien Lokalisator und Kontakt Sektor Tomographie wurden ebenfalls studiert

RESUMÉ

L auteur montre l intéret clinique du diagnostic des tumeurs cérébrales par les ultra sons avec la méthode des impulsions Il a utilisé l appareil ultrasonique standard (Aloka Model SSD 2 A scope indication method) et les fréquences convenables étaient de 1 à 10 mégacycles L auteur a mesuré *l impédance acoustique* du cerveau normal et des tumeurs cérébrales Il a trouvé des échos de tumeur dans 80 cas sur 111 cas de tumeur vérifiés par opération ou par autopsie Il a aussi étudié un localisateur de ligne médiane et un dispositif de tomographie

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Diagnosis and localization of the brain tumor In 300 cases of suspected brain tumor confirmation of the site of the tumor had been obtained by operation and/or autopsy in 111 patients Of these cases, the pathologic diagnoses were glioma in 44 patients, meningioma in 13, neurinoma in 13, pituitary adenoma in 9, metastatic tumor in 8, craniopharyngioma in 6, cholesteatoma in 2, tuberculoma in 2, plexus papilloma in 2, and other tumors in 5

Tumor echoes were positive in 80 of the 111 patients Of 111 with tumors 55 had cerebral tumors and 53 of these had a positive echo In 30 cases of infratentorial tumors, 10 cases were correctly diagnosed (Table 4)

Our findings in some of these cases are illustrated in Figs 9 to 13

Ultrasonotomography of the brain

As stated in a foregoing section, the A scope indication method is useful for various clinical diagnoses but sometimes the analysis of the echo patterns is not easy Therefore, in order to determine the accurate positions of the brain tumors we made our studies with ultrasound tomographies

In the case of brain tomography, a B scope indication method is not completely successful as the convex form of the skull and the large attenuation of the skull are barriers to ultrasonic propagation

The present writers have therefore been studying the application of contact scanning to overcome this difficulty The principle is as follows A transducer is placed directly on the surface of the scalp in the desired plane Ultrasonic energy is emitted radially from the transducer to scan the plane section of the brain On the cathode ray tube screen the direction of a time base is varied in synchronization to the direction of the axis of the transducer The information of the axis is picked up electrically by a resolver and sent to the deflection coil of the cathode ray tube (Fig 14)

Efforts to improve the apparatus and its resolving power are in progress Some patterns obtained by ultrasonotomography are shown in Figs 15 and 16 A new phase in the diagnosis of brain lesions should soon be at hand

SUMMARY

The clinical value of ultrasonic diagnosis of brain tumors by means of the pulse method is presented The standard ultrasonic apparatus (Aloka Model SSD 2 A scope indication method) was used and suitable frequencies were 1 to 10 megacycles The acoustic impedance of the normal brain and of brain tumor were measured Tumor echoes were positive in 80 out of 111 patients with brain tumor verified by operation and autopsy A midline locator and ultrasonotomography were also studied

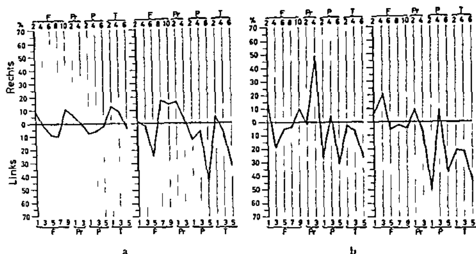
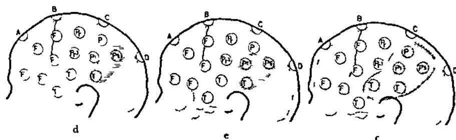


Abb. 1. Gammaencephalographische Verlaufsuntersuchungen bei einem Kranken mit einem Glioblastom (operative Therapie). a) Vor Operation. b) 7 Monate nach der Operation. c) 9 Monate nach der Operation. (d—f entsprechen a—c)



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VERLAUFSUNTERSUCHUNGEN BEI HIRNTUMOREN MIT RADIOAKTIVEN ISOTOPEN

von

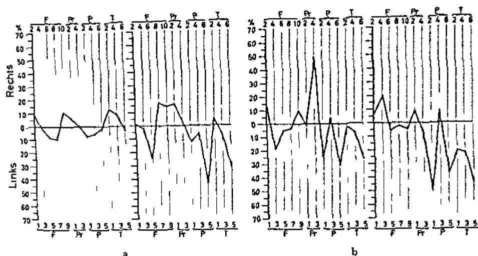
SIGURD WENDE

Die Gamma-Encephalographie mit RISA (radioaktives jodiertes Serum-Albumin) erlaubt es, Beginn und Ablauf der Strahlen-Einwirkung auf das Gehirn zu erfassen. Gamma-encephalographische Verlaufsuntersuchungen geben ferner Aufschluss über das Wachstum eines Hirntumors. Gleichzeitig kann durch diese Verlaufsuntersuchungen der Erfolg einer operativen Therapie oder einer Strahlen-Behandlung bestimmt werden.

Unsere Untersuchungsergebnisse lassen sich in 3 Gruppen zusammenfassen.

In der *1. Gruppe* handelt es sich um Kranke, bei denen nur eine operative Behandlung erfolgte.

Die Abb. 1a zeigt den gamma-encephalographischen Befund eines Patienten mit einem parieto-temporo-occipital gelegenen Glioblastom. Die Geschwulst konnte operativ weitgehend entfernt werden, der Kranke verliess im guten Zustand die Klinik. Bei einer Kontroll-Untersuchung 7 Monate nach der Operation hatte sich die neurologische Symptomatik nicht verändert. Im Gamma-Encephalogramm war jedoch eine Grössenzunahme der Isotopen-Anreicherung zu verzeichnen (Abb. 1b), die für ein Rezidiv und für ein



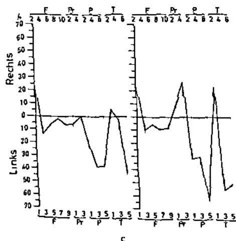
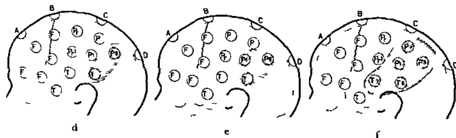


Abb. 1. Gamma-encephalographische Verlaufsuntersuchungen bei einem Kranken mit einem Glioblastom (operative Therapie). a) Vor Operation. b) 7 Monate nach der Operation. c) 9 Monate nach der Operation (d—f entsprechen a—c)



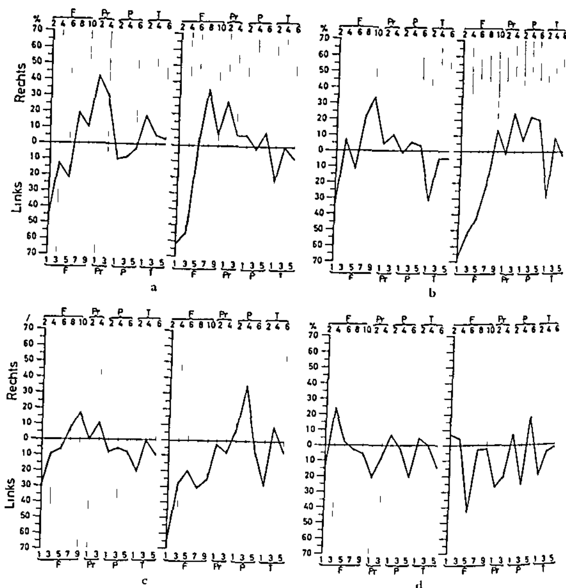


Abb. 2. Gammaencephalographische Verlaufsuntersuchungen bei einer Kranken mit einem Glioblastom (guter Erfolg der Strahlen-Therapie, reversibles Hirnödem). a) Vor Strahlen-Therapie. b) Nach Bestrahlung von 2 500 R. c) Nach 5 000 R. d) 9 Wochen nach der Strahlungbehandlung

weiteres Tumor-Wachstum sprach. Wiederum 2 Monate später, also 9 Monate nach der Operation, kam es dann zu einer schnell einsetzenden Verschlechterung des Allgemeinzustandes des Patienten. Die Isotopen-Untersuchung bestätigte das rasche Tumor-Wachstum (Abb. 1c). Dabei ist nicht nur eine Grössenzunahme der Isotopen-Speicherung festzustellen, sondern es liegt auch eine verstärkte Aufnahme der radioaktiven Substanz im Tumor-Gebiet vor.

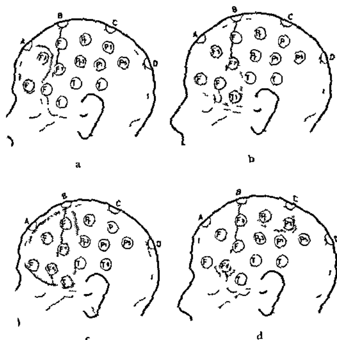


Abb 3 a—d entsprechen Abb 2 a—d

An dem Beispiel eines weiteren Kranken soll die *2 Gruppe* geschildert werden bei der nach einer reversiblen Permeabilitats Storung der Blut Hirn Schranke ein guter Erfolg der Strahlen Therapie zu verzeichnen ist

Bei einer Kranken mit einem Glioblastom li frontal war mit dem Gamma Encephalogramm vor der Rontgen Therapie Lokalisation und Ausdehnung der Geschwulst genau abzugrenzen (Abb 2a) Nach einer Bestrahlung von 2 500 R hatte sich der Bezirk der pathologischen Isotopen Speicherung vergrossert (Abb 2b) Im klinischen Zustand war eine massige Verschlechterung eingetreten Eine weitere Grossenzunahme der Isotopen Anreicherung war nach 5 000 R zu beobachten (Abb 2c) Durch die Rontgen Therapie trat also eine umschriebene verstarkte Permeabilitats Storung der Blut Hirn Schranke im Tumor Gebiet und in seiner Umgebung auf 9 Wochen nach der Strahlen Behandlung war die Kranke bei einer Kontroll Untersuchung weit gehend beschwerdefrei Auch das Gamma Encephalogramm hatte sich bis auf noch nachweisbare Tumor Reste wieder normalisiert (Abb 2d)

Bei der *3 Gruppe* von Hirntumor Patienten lasst sich mit dem Gamma Encephalogramm der Einfluss der Rontgen Therapie auf die Geschwulst

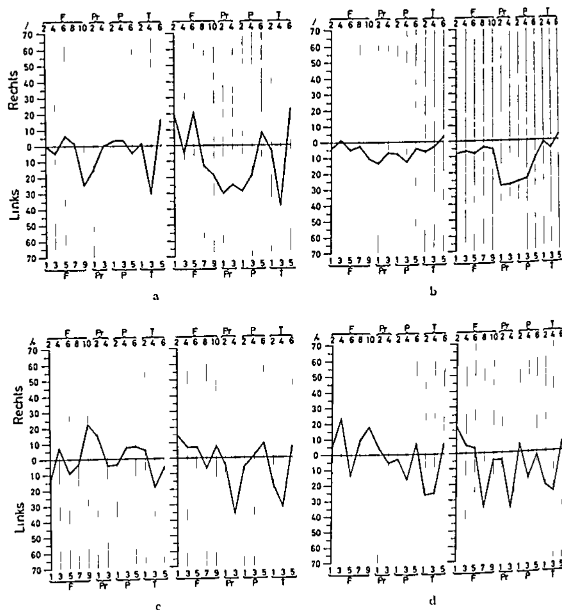


Abb 4 Gamma encephalographische Verlaufsuntersuchungen bei einer Kranken mit einem Oligodendrogliom (Ruckbildung des Hirntumors unter Strahlen Therapie Grossenzunahme der Geschwulst 10 Wochen nach der Behandlung) a) Vor Strahlenbehandlung b) Nach 2 500 R c) Nach 5 000 R d) 10 Wochen nach der Strahlenbehandlung

ebenfalls beweisen, eine vorubergehende Permeabilitats Storung der Blut Hirn Schranke ist jedoch nicht erkennbar

Abb 4a gibt das Gamma Encephalogramm einer Kranken mit einem Oligodendrogliom vor Therapie Beginn wieder Nach einer Bestrahlung von 2 500 R hatte sich der Hirntumor zuruckgebildet (Abb 4b) Nach 5 000 R

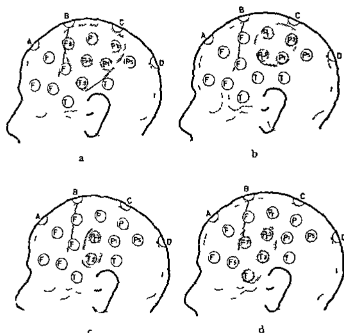


Abb 5 a—d entsprechen Abb 4 a—d

war eine weitere Ruckbildung der pathologischen Isotopen Anreicherung zu verzeichnen (Abb 4c) Aber schon 10 Wochen nach der Strahlen Therapie machte sich wieder eine Verschlechterung der neurologischen Symptomatik bemerkbar Das Gamma Encephalogramm bewies die Grossenzunahme des Tumors (Abb 4d)

Auch bei dieser Gruppe von Patienten geht also der Befund der Isotopen Untersuchung mit dem klinischen Befund parallel Allderdings ist hier eine durch die Strahlen Therapie ausgeloste Permeabilitats Storung der Blut Hirn Schranke nicht zu beobachten

Zur Frage des Zusammenhanges zwischen Malignitat einer Geschwulst und Speicherung der radioaktiven Substanz im Tumor Gebiet sei folgende Untersuchung angefuhrt

Bei dem Kranken bestand ein Astrocytom das 2 1/2 Jahre nach der ersten Operation nochmals operativ behandelt wurde Die erste Gamma Encephalographie bewies die Tumor Ausdehnung sie zeigte auch die ausgepragte Isotopen Aufnahme im Geschwulst Bereich Es liess sich ein Impuls Uberwiegen von fast 60 % erkennen (Abb 6a)

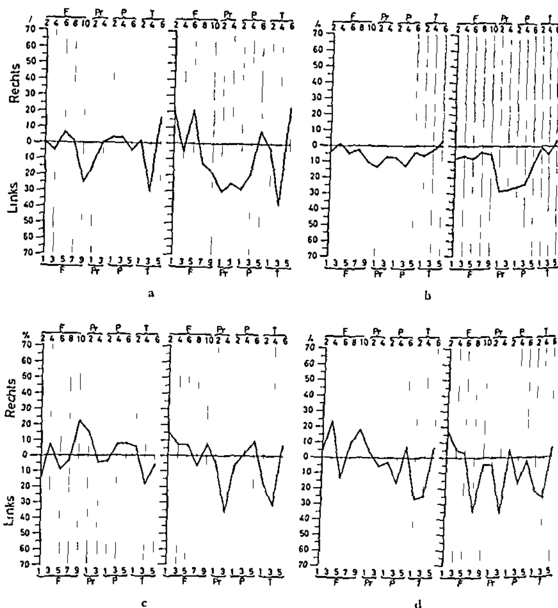


Abb. 4. Gamma-encephalographische Verlaufsuntersuchungen bei einer Kranken mit einem Oligodendrogliom (Rückbildung des Hirntumors unter Strahlen-Therapie. Grössenzunahme der Geschwulst 10 Wochen nach der Behandlung). a) Vor Strahlenbehandlung. b) Nach 2 500 R. c) Nach 5 000 R. d) 10 Wochen nach der Strahlenbehandlung

ebenfalls beweisen, eine vorübergehende Permeabilitäts-Störung der Blut-Hirn-Schranke ist jedoch nicht erkennbar.

Abb. 4a gibt das Gamma-Encephalogramm einer Kranken mit einem Oligodendrogliom vor Therapie-Beginn wieder. Nach einer Bestrahlung von 2 500 R hatte sich der Hirntumor zurückgebildet (Abb. 4b). Nach 5 000 R

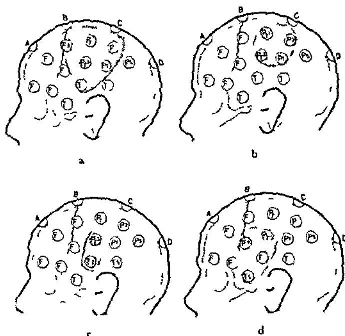


Abb. 5 a–d entsprechen Abb. 4 a–d

war eine weitere Rückbildung der pathologischen Isotopen-Anreicherung zu verzeichnen (Abb. 4c). Aber schon 10 Wochen nach der Strahlen-Therapie machte sich wieder eine Verschlechterung der neurologischen Symptomatik bemerkbar. Das Gamma-Encephalogramm bewies die Grössenzunahme des Tumors (Abb. 4d).

Auch bei dieser Gruppe von Patienten geht also der Befund der Isotopen-Untersuchung mit dem klinischen Befund parallel. Allderdings ist hier eine durch die Strahlen-Therapie ausgelöste Permeabilitäts-Störung der Blut-Hirn-Schranke nicht zu beobachten.

Zur Frage des Zusammenhanges zwischen Malignität einer Geschwulst und Speicherung der radioaktiven Substanz im Tumor-Gebiet sei folgende Untersuchung angeführt.

Bei dem Kranken bestand ein Astrocytom, das 2 1/2 Jahre nach der ersten Operation nochmals operativ behandelt wurde. Die erste Gamma-Encephalographie bewies die Tumor-Ausdehnung; sie zeigte auch die ausgeprägte Isotopen-Aufnahme im Geschwulst-Bereich. Es liess sich ein Impuls-Überwiegen von fast 60 % erkennen (Abb. 6a).

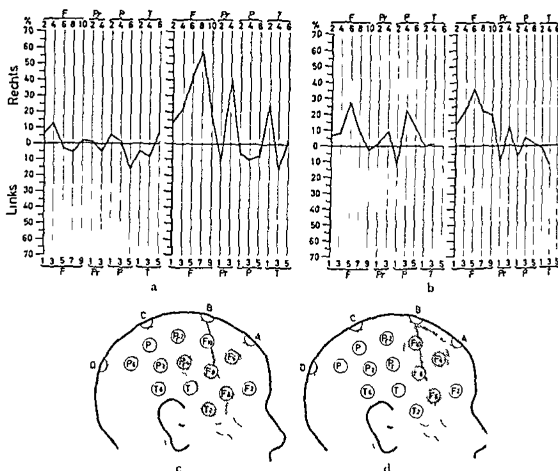


Abb 6 Abnahme der Speicherungs Intensität bei einem Astrocytom trotz zunehmender Malignisierung der Geschwulst a) Vor der ersten Operation b) Vor der zweiten Operation (c und d entsprechen a und b)

Vor der zweiten Operation wurde die Gamma Encephalographie wiederholt Der Tumor war auch jetzt abgrenzbar Die Intensität der Isotopen Speicherung war jedoch nicht so ausgeprägt wie bei der ersten Untersuchung, die Differenz Prozent Kurven wiesen nur ein Impuls Überwiegen von 45 % auf (Abb 6b)

Bei dem Vergleich der histologischen Präparate konnte aber eindeutig nachgewiesen werden, dass der Tumor erheblich an Malignität zugenommen hatte

Es ist daraus abzuleiten, dass das Gamma Encephalogramm bei bösartigen Tumoren zwar die Grossenausdehnung der Geschwulst und das Vorliegen eines Rezidivs anzeigt zum Grad der Malignität kann jedoch auf Grund der Isotopen Untersuchung nicht Stellung genommen werden

ZUSAMMENFASSUNG

Durch die Gamma Encephalographie lasst sich die Ausdehnung einer Hirngeschwulst und ihr allmahliches Wachstum exakt bestimmen Der Therapie Erfolg bei der Bestrahlung bosartiger Hirntumoren kann durch die Gamma Encephalographie objektiviert werden Die Intensitat der Isotopen Speicherung im Tumor Gebiet geht nicht mit der Malignitat der Hirngeschwulst parallel

SUMMARY

Gamma encephalography enables the extent of a cerebral tumour and its gradual increase to be determined The effectiveness of radiotherapeutic measures in cerebral malignant neoplasms can also be checked by this method The storage of isotopes within a brain tumour and its degree of malignancy are not correlated

RESUME

La gamma encephalographie permet de determiner exactement l extension et la croissance progressive d une tumeur cerebrale Elle permet d objectiver le resultat therapeutique de l irradiation des tumeurs cerebrale malignes L intensité de la fixation de l isotope dans le territoire tumoral n est pas parallele a la malignite de la tumeur cerébrale

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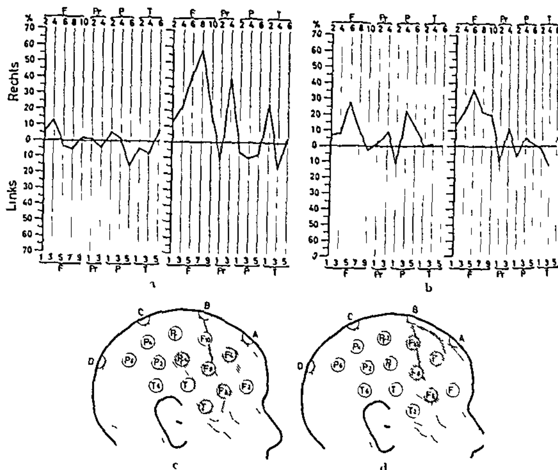


Abb. 6. Abnahme der Speicherungs-Intensität bei einem Astrocytom trotz zunehmender Malignisierung der Geschwulst. a) Vor der ersten Operation. b) Vor der zweiten Operation. (c und d entsprechen a und b)

Vor der zweiten Operation wurde die Gamma-Encephalographie wiederholt. Der Tumor war auch jetzt abgrenzbar. Die Intensität der Isotopen-Speicherung war jedoch nicht so ausgeprägt wie bei der ersten Untersuchung, die Differenz-Prozent-Kurven wiesen nur ein Impuls-Überwiegen von 35 % auf (Abb. 6b).

Bei dem Vergleich der histologischen Präparate konnte aber eindeutig nachgewiesen werden, dass der Tumor erheblich an Malignität zugenommen hatte.

Es ist daraus abzuleiten, dass das Gamma-Encephalogramm bei bösartigen Tumoren zwar die Grössenausdehnung der Geschwulst und das Vorliegen eines Rezidivs anzeigt, zum Grad der Malignität kann jedoch auf Grund der Isotopen-Untersuchung nicht Stellung genommen werden.

ZUSAMMENFASSUNG

Durch die Gamma Encephalographie lasst sich die Ausdehnung einer Hirngeschwulst und ihr allmahliches Wachstum exakt bestimmen Der Therapie Erfolg bei der Bestrahlung bosartiger Hirntumoren kann durch die Gamma Encephalographie objektiviert werden Die Intensitat der Isotopen Speicherung im Tumor Gebiet geht nicht mit der Malignitat der Hirngeschwulst parallel

SUMMARY

Gamma encephalography enables the extent of a cerebral tumour and its gradual increase to be determined The effectiveness of radiotherapeutic measures in cerebral malignant neoplasms can also be checked by this method The storage of isotopes within a brain tumour and its degree of malignancy are not correlated

RÉSUMÉ

La gamma encéphalographie permet de déterminer exactement l extension et la croissance progressive d une tumeur cerebrale Elle permet d objectiver le résultat thérapeutique de l irradiation des tumeurs cérebrales malignes L intensité de la fixation de l isotope dans le territoire tumoral n est pas parallele a la malignite de la tumeur cérébrale

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FROM QUEEN'S UNIVERSITY, KINGSTON, ONTARIO, CANADA

STUDIES IN ULTRASONIC ECHO-ENCEPHALOGRAPHY II

An objective technique for the A scan presentation of the cerebral midline structures

by

D NALDRETT WHITE and J B BLANCHARD

While echoencephalography using an A scan presentation for examination of the cerebral midline structures is a remarkably attractive technique because of its speed and simplicity and safety, some of us working in the field have been concerned by its lack of objectivity and by our lack of ability to identify with certainty the origin of most of the multiplicity of echoes that can be seen on the oscilloscope The need for some objective control is all the more important in view of the plethora of high amplitude echoes that, with patience can be evoked at almost any depth from the transducer, particularly on the near side of the midline Such a need appeared to us to become all the greater after an initial experience with this technique (8) had shown that observer bias and poor experimental technique had greatly exaggerated the reliability of the examination We believe firmly that it is only a matter of time before compound scanning of the brain is sufficiently developed to give satisfactory tomograms of the ventricular system (7) When this development has taken place the position of A scan echoencephalography will have to be reconsidered At such a time it would appear to us that the only justification there could be for the continuation of a method that gives so much less information than will be

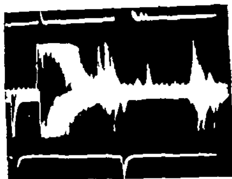


Fig 1 Time exposure of A scan echoencephalogram from patient shown by cerebral angiography *to have no displacement of the* cerebral midline taken from point perpendicular to centre of incisura in the falx cerebri and above the foramen of Munro Position of cerebral midline is at intersection of the start of the central deflections in top and bottom traces which are of transmission impulses across the skull The start of the lower transmission pulses is denoted by the small deflection in line *with the initial deflections in* the other three traces The larger deflection to the left of this is an artefact (Read from left to right) No high amplitude echo can be seen in the two central traces at the site of the cerebral midline

available with compound scanning would be its much greater simplicity and the smaller cost of the equipment Under these circumstances it is possible to envisage the time when equipment for A scan echoencephalography will be widely available even in small hospitals and doctors offices and possibly also in mobile units capable of examining large segments of the healthy population It would thus be used as a screening device to pick up cases with significant shift of the cerebral midline structures both from the population at large *and from patients with indefinite symptoms such as headache who might be* suffering from unilateral cerebral disease

If this situation were to come to pass then it is obvious that the technique must be reasonably *simple* and quick *but more important it must be made* quite objective free from observer bias and preferably capable of giving a graphic record which could be readily interpreted by any informed person We feel that the technique as it has been developed up to the present time lacks true objectivity We feel moreover that while individual workers may, with experience acquire much skill and reliability with the technique that if it is to have any future application once the difficulties of compound scanning of the brain have been solved then it must be capable of being used by relatively unskilled workers and in their hands be able to give some readily interpretable graphic record We therefore determined to try to evolve a technique that was not only objective but was capable of being recorded in a graphic form which could be interpreted by any person familiar with the method

The identification of the M echo

Initially we were concerned with the source of the M echo as well as the other high amplitude echoes seen in the A scan The results of these investigations will be reported later elsewhere The purpose of this paper is to describe

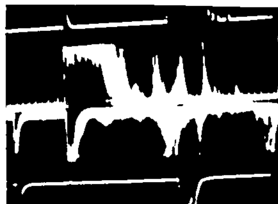


Fig. 2. Time exposure A scan from a subject with a 3—5 mm shift of the third ventricle to the left. Taken from the same position and using the same conventions as in fig. 1.



Fig. 3. Time exposure A scan from the same patient as in fig. 2 taken one week later from the same position and using the same conventions.

an endeavour to evolve a technique that would both reliably and consistently identify the M echo from other echoes and measure its position with respect to the mid line of the cranial contents.

There seem to be few properties upon which most authorities are agreed which are peculiar to and characteristic of, the M echo and which distinguish it from other echoes. JEPPSSON (5) stresses that a true M echo has the double peaked shape of an M. Not every other worker agrees that such is the case and some workers have stated it often is seen as a single high peak with twin shoulder peaks at lower amplitude on either side. While we would agree that the M echo usually has one or other of these characteristic shapes its pattern on the oscilloscope is, in our experience, so evanescent that we have been unable to photograph this consistently. Thus we have been unable to use the shape of the M echo as a means of identification. It is probably this factor more than any other that enables the skilled worker to identify one echo out of the multiplicity appearing on the oscilloscope as the M echo. However since, in our hands at least, it has proved impossible to record this shape graphically with any consistency, we have been unable to use this property as a means of identifying the M echo.

JEPPSSON (5) also stresses, as have subsequent workers, the fact that the M echo pulsates. However without special techniques involving moving films or other recording devices, it is difficult to provide a graphic trace identifying pulsating echoes and separating them from those that are stationary. It is possible however that this property of the M echo could be used for its more certain identification in the way developed by EIFERT (2) and EDLER (1).



Fig 4 Time exposure A scan from patient with no displacement of his midline taken from a point just behind the vertical plane passing through the anterior margin of the pinna and at level just above the pinna Two clear cut high amplitude echoes in the midline

Most workers do seem agreed that the M echo is the echo of highest amplitude and the most persistent of those seen across the length of an A scan We decided to test the validity of this belief by means of time exposures taken during the elicitation of the M echo by scanning Under these circumstances it would be expected that the highest amplitude echoes would stand out above the lower amplitude echoes and moreover the persistent high amplitude echoes would be clearly distinguished from the evanescent high amplitude echoes coming from varying and differing positions across the scan by forming a more intense image on the negative

At first we investigated the echoes that were to be found from a scan performed by a transducer placed 5 cm above the mid point of the line joining the external canthus of the orbit and the external auditory meatus At this position the transducer would be perpendicularly above the foramen of Munro and approximately at the mid point in the incisura of the falx cerebri and it is at this position that one would expect to find and indeed does find radiologically the greatest degree of shift of the cerebral mid line with various unilateral intra cranial lesions However it was found that the time exposures rarely if ever allowed the identification of a single echo as being of highest amplitude and greatest persistence and when they did they often were seen in a position not corresponding to the position of the cerebral mid line as determined by pneumography or angiography

Fig 1 shows that in a patient who was known to have no shift of the cerebral mid line structures the most persistent echoes of highest amplitude were found to the near side of the midline both with scans from the left and right temporal regions and no high amplitude echo was distinguishable from the site of the true midline Perhaps the most damning feature of this procedure was its complete lack of reproducibility from day to day or even hour to hour

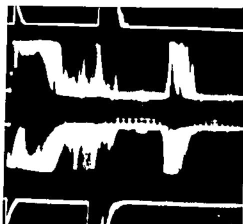


Fig 5 Same conditions as in fig 4 from another patient The highest amplitude and most persistent echoes are in the midline

Fig 2 shows a time exposure from a patient shown by pneumography to have a slight midline shift to the left By the convention used in our display system and to be described below, the M echoes should have appeared on the upper echo trace 1 5—2 mm to the left of the intersection of the two transmission pulses and that on the lower echo trace the same amount to its right No echoes will be noted at these sites and when the time exposure was repeated a week later (Fig 3) a very different outline was obtained, this time showing a high amplitude and persistent echo on the lower trace from the right hand transducer to be at the site of the theoretical midline but no corresponding echo on the upper trace from the left hand transducer but instead one well to the left of the midline

Our complete inability to obtain reliable and reproducible results with time exposures was paralleled by our inability to obtain reliable scans from this position by the conventional techniques This experience is in accord with that of most other workers who are agreed that while occasional scans can be made from the pre auricular position these are the exception and most scans in this area merely produce a confusing complexity of high amplitude echoes It is unfortunate that this is the case since if ultrasonic scanning of the cerebral midline structures is to be developed into a sensitive investigative tool evidence of the earliest and greatest shifts would be expected to be obtained from scans of the structures in the centre of the incisura of the falx where shifts would be expected to be maximal

We next investigated the position just above and behind the anterior and superior margin of the pinna It is from this position that most investigators are agreed that reliable identification of the M echo can almost always be made From this position the transducer when perpendicular to the skull would be expected to radiate a beam whose central axis passes close to the pineal gland

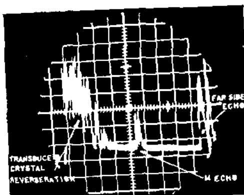


Fig 6 A typical A scan across the temporal regions of the head

and the posterior part of the third ventricle Here our results were more gratifying and from this position in every case we were able by means of exposures to demonstrate a maximal echo which was single and reproducible with repeated examinations and which we believe to be the M echo (Fig 4) The M echo did not always stand out so well as in Fig 4 more often other echoes were seen on either side of it especially the near side But in every case one echo alone which we identify as the M echo was distinguishable from these other echoes by its greater amplitude and its greater persistence, the latter of course causing more intense exposure of the photographic negative at its site (Fig 5) It is interesting that echoes are seen in Fig 5 symmetrically on either side of the M echo which naturally raises the possibility that they are originating from the two lateral ventricles

Localisation of the M echo with respect to the midline

Having found what appeared to be a satisfactory reliable reproducible and graphic method of identifying the M echo we then turned our attention to the problem of measuring the position of the M echo in relation to the theoretical cerebral midline Various investigators have endeavoured to make this measurement Ford & Ambrose (3) in their series of patients checked each representation to make sure that when the distance represented on the oscilloscope from one transducer *to the far side of the skull was equal* then the sum of the two midline echoes would equal the distance across the skull This method in our opinion is not exact Firstly the mass of echoes associated with the crystal of the transducer is such that in our experience any echoes from the near side of the skull are completely obliterated The only constant feature of this mass of echoes (Fig 6) is their onset which we presume to correspond topographically with the site of the transducer face which is of course, in contact with the scalp

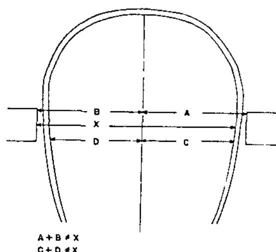


Fig 7 In measuring the position of the mid line neither $A + B$ nor $D + C$ equals X

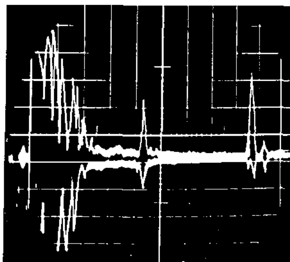


Fig 8 Two superimposed M echoes using a comparator

and external to the outer table of the skull Secondly, the echoes from the far side of the skull characteristically consist of a pair of echoes which we have assumed (though this has never been proved) to represent the inner and outer tables of the skull

Thus, we believe that the method described by FORD & AMBROSE cannot properly measure the skull diameter but measures the distance from the crystal face to the inner or outer table of the far side of the skull (X in Fig 7) and then endeavours to equate this distance with either the sum of the distances from the transducer face to the midline on each side (A+B Fig 7) or the sum of the distances from the midline to the inner or outer tables on each side (D+C, Fig 7) Since the scalp in the temporal region is about 3 mm thick and the skull another 3 mm thick, we believe that this method even under the most favourable conditions, either overestimates the sum of the two distances, or underestimates the measurement of the apparent skull diameter by the thickness of the skull and scalp on one side If there is any uncertainty in identifying either the outer or inner tables of the skull on the opposite side, then these errors may be either increased or decreased This may be important since it is not always easy to elicit these far side echoes in the characteristic paired fashion that would make the identification of the echo from either the outer or inner table of the far side certain

A better method would appear to be that suggested by Smith Kline Instruments, the manufacturers of the Echoline machine They advise that the scalp



Fig 9 False M-echo across a tank filled with water only Top and bottom traces are transmission pulses between the two transducers The two echo traces obtained with a comparator show apparently a reflection from some midline structure which is not present

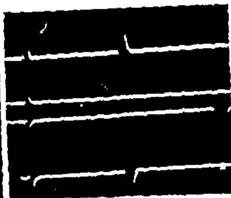


Fig 10 Same as in fig 9 but with the left hand transducer removed from contact with the water bath Disappearance of *both* M echoes Top and bottom traces are transmission pulses obtained with both transducers applied to the tank

on the far side of the skull be identified by moving it with a finger until the echo from it distal to the twin echoes from the far side of the skull is identified and its position then marked on the oscilloscope or a scale The true midline will then be along the scan halfway between this mark and the onset of the crystal reverberation While this is undoubtedly an accurate method to our mind it has the disadvantage of showing the operator probably before he attempts to elicit the M echo just where a midline echo would be expected to lie or alternatively where a displaced M echo might be sought Such a method therefore lays itself open to the occurrence of observer bias which as we have already mentioned we fear might easily develop with this technique (8)

GORDON (4) attempted to overcome these difficulties by introducing a comparator unit which enabled the echoes from the two receivers to be represented on the oscilloscope simultaneously the one below the other and inverted in form (Fig 8) When the two traces on the oscilloscope were properly adjusted the first crystal echo from one transceiver would appear exactly above that from the other and the echoes from each far side of the skull would be similarly aligned Under these circumstances the two M echoes should be seen exactly above each other if the midline structures were undisplaced Such a representation would appear to be an ideal method of easily detecting shifts in the midline However in our hands the comparator unit has not proved to be a very reliable tool Firstly the relay that is needed to switch rapidly from one receiver unit to the other proved unreliable and electrically noisy Secondly and much the

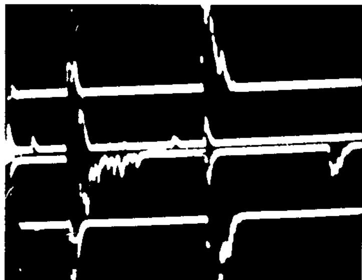


Fig. 11. Two apparent M echoes superimposed above each other (middle traces) and thus presumably coming from a surface equidistant from each transducer in left and right temporal areas respectively, i.e. from the midline. Top and bottom traces are transmission pulses across the skull to show position of a midline echo



Fig. 12. Angiogram from the patient whose echoencephalogram was shown in fig. 11

more important drawback, is the fact that with two transducers on opposite sides of the skull at the same time as the transmission pulse is jittered to one transducer, some of this energy is also conveyed to the transducer which is meant to be inactive by means of 'cross talk' in the jittering relay. Thus, at the time the active transceiver is receiving echoes from its own pulse it also receives, as a straight transmission pulse, the cross induced energy from the other transducer on the opposite side of the skull. This induced transmission pulse will be received by the active transceiver at the same distance along the X axis of the oscilloscope as echoes from the mid point between the two transducers. Thus each transceiver is capable of recording a false midline echo which in fact is a straight transmission pulse from the opposite transducer which has been activated by cross talk across the jittering relay. This false echo with the comparator is demonstrated (Fig. 9) by a scan across an otherwise empty, water filled bath apparently showing a midline echoing surface. As soon as one transducer is removed from contact with the side of the tank (Fig. 10) both M echoes disappear but the far side echo remains for the transducer in contact with the side of the tank. The two transmission pulses were superimposed by a double exposure for reference and, of course, were obtained with the two transducers applied to the tank. That this error can falsify M echo determinations from the human skull is shown by Fig. 11 where two apparent

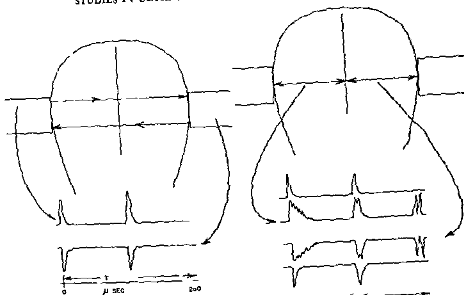


Fig 13

Fig 14

Fig 13 A transmission pulse one way across the skull

Fig 14 The one way transmission pulse travels the same distance as an echo pulse to the true mid line and back to the transducer Thus both transmission pulses and both M echo pulses will all lie the same distance along the time base when the mid line is undisplaced

M echoes are superimposed so it might be concluded that the midline was not displaced Fig 12 shows the angiogram from the same patient and the gross displacement present of his midline structures Thus we do not feel that the comparator as developed by GORDON, is of any help in identifying the M echo and indeed is positively misleading in that it gives rise to low amplitude pulses simulating echoes from the midline

Both LITHANDER (6) in 1960 and JEPPSSON (5) in 1961 chose another method to try and indicate the position where the true midline might be expected and to eliminate the tedium of measurements from deflections whose true significance or position were unclear They superimposed a third oscilloscope tracing upon the two traces each representing echoes from beams entering from either side of the skull This third trace was obtained not by recording the echoes received from pulses of ultrasound sent out by the same transducer as was the case with the two conventional echo traces but used one probe as a transmitter and the other as a receiver so that the linear deflection of this trace represented the time taken for the sound to traverse one way across the skull and thus would equal the time taken for a sound impulse to arrive at the true midline and to

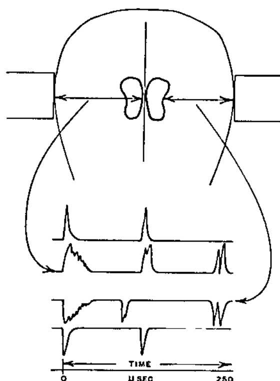


Fig 15

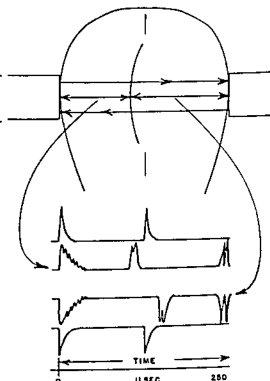


Fig 16

Fig 15 Echoes from different structures will give echo pulses which neither lie at the same distance along the time base as the transmission pulses nor symmetrically before and after the transmission pulses

Fig 16 In shifts of the mid line the two M echo pulses are seen symmetrically an equal time before and after the two transmission pulses

be reflected back to the original transmitting transceiver Thus, true shifts of the midline should be apparent with LITHANDER's control trace by showing symmetrical displacement of the conventional midline echoes, one on each side of the control deflection

Equipment and technique

In our endeavour to increase the objectivity of the technique we have used both GORDON's and LITHANDER's methods with slight modifications

We have modified LITHANDER's method so that instead of a single transmission pulse we superimpose two on our photographs The first is seen in the top trace and is the transmission from left transducer to right hand receiver the other is seen in the bottom trace from right transducer to left receiver (Fig 13) The two middle traces are our echo traces, the top one being from the left

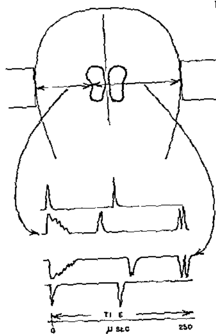


Fig 17

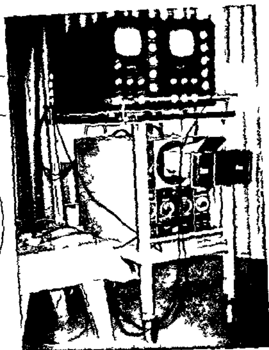


Fig 18

Fig 17 A false M echo such as might be recorded if both echo traces recorded reflections at high amplitude from a single para median interface

Fig 18 Lay out of the equipment used

hand transducer also acting as a receiver and *the lower from the* right hand transceiver (Fig 14) Thus in any case where the midline structures are not displaced the M echoes from them will lie *in the same* line as the line intersecting the onset of the two *transmission* pulses always providing that in every case the initial echoes from the crystals are, in all four traces accurately aligned above each other

It will be *seen that the* advantage of *this method* is *that it should enable one* to say quite definitely whether two echoes on the middle traces are coming from *one* and the same object Thus, Fig 15 if *the* echo on one side was recorded from a lateral ventricle (say) and *on the* other side from the midline this would be immediately apparent because while the echo on the lower echo trace is displaced towards the *transducer* that on the upper echo trace is in the midline Thus they cannot be *coming from* the same structure On the other

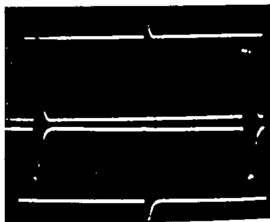


Fig 19 Absence of cross talk between the two transmitters which are scanning across a water tank in the same way as shown in figs 9 and 10

hand, if the midline is displaced (Fig 16) and echoes are obtained from it on either side, this will be immediately apparent by showing a shift of the two echo traces by an equal amount to either side of the intersecting transmission pulses The only source of error that is possible with this control (Fig 17) is the situation where both transducers record echoes from an identical reflecting surface which is not part of the midline structures We hoped that this would be an unlikely occurrence not only because the greater degree of attenuation of the echo coming from the far side of the midline might make it hard to receive such echoes at high amplitude, but also because we thought many such reflecting surfaces might be curved and therefore liable to give rise to echoes of greatly different strength depending whether these were evoked from the concave or the convex surfaces

Our other modification is the use of two separate flaw detectors If one detector only is used we found that it was impossible to avoid the appearance of a straight transmission pulse in the position of the M echo without the expense and difficulty of elaborate co axial shielding and switching Only if two separate flaw detectors are employed and their activity alternately displayed on a common presentation system do we feel that it is possible to avoid completely any possibility of cross talk between the two transducers by means of straight transmission pulses which will of course, give rise to false M echoes The layout of our equipment is shown in Fig 18 and the absence of cross talk in Fig 19, using the same water bath which in Fig 9 showed the false M echo where no reflecting surface was present due to transmission pulses between the two transceivers Fig 20 shows the wiring diagram of our equipment A simple foot switch enables us to change from using each transducer alternately as both transmitter and receiver for intra cerebral echoes to a transmission system in which the pulse from the left to the right temporal transducer is represented

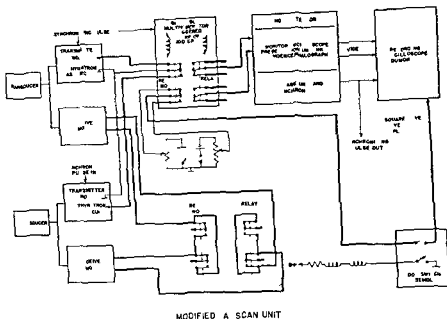


Fig 20 Diagram of the modification of the comparator with transmission pulse control

at the top of the trace and that from the right to the left temporal transducer at the bottom The presentation system is adjusted so that these two transmission pulses are exactly superimposed and approximately in the midline of the oscilloscope

The presentation system is monitored on to a second oscilloscope to which a camera is connected The examination is carried out in two parts each being recorded by the camera on a separate single exposure Firstly with one transducer applied *to the skull just behind the vertical line passing through* the front of the pinna and at a level just above the pinna a time exposure is taken for about one minute during which time the operator endeavours to elicit and hold on the oscilloscope echoes of maximal amplitude The procedure is then repeated with the second transducer at the homologous area on the opposite side and a further time exposure made on the same film After these exposures have been made two transmission pulses are superimposed on the same polaroid negative This polaroid photograph is then developed and examined for the presence of a single echo of maximal amplitude and persistence (Figs 4 and 5) in each echo trace The approximate position of these maximal

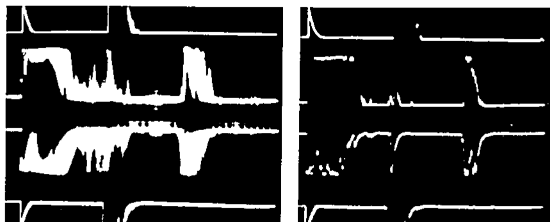


Fig 21 Time exposure and instantaneous exposure which are considered satisfactory and fulfil the five separate criteria enumerated in the text The scan shows an undisplaced M echo from a patient shown by pneumography to have no displacement of the midline structures

echoes is then noted with respect to the line intersecting the two transmission pulses

The whole procedure is then repeated but this time no time exposure is made Instead we endeavour to display on the trace high amplitude echoes in the same position as the maximal echoes seen in the time exposure When such echoes are being displayed satisfactorily an instantaneous exposure is made, first on the one side, then on the other, and finally the two transmission pulses are also superimposed on the same negative The photograph is developed and examined to see that the following criteria have been fulfilled

Firstly, all four initial crystal deflections must be aligned Secondly, the echoes from the far side of the skull in the two echo traces must be superimposed Thirdly, the M echo deflections must (1) lie each in the same position as the maximal echoes demonstrated in the time exposure, (2) be of adequate amplitude and sharpness with a clean take off from the baseline, and (3) lie either in the line intersecting the two transmission pulses or symmetrically to either side of it (Fig 21) If the photograph does not fulfil all these criteria the examination is immediately repeated until a satisfactory picture is obtained It is for this reason that we use polaroid film so that no delay occurs in repeating an unsatisfactory examination The instantaneous photograph is taken, of course, to allow accurate measurement of the M echo pulses at their take off from the baseline This cannot be seen accurately in the time exposures where the contours of the maximal echoes are blurred, especially at their bases

It will be noted that both in the time exposure and the instantaneous photographs we display the echoes from each side separately and not simultaneously as could easily be done We do this in order to try and eliminate all

observer bias since we found that when the two echoes were displayed simultaneously the operator often tried to manipulate the transducers so that the high amplitude echoes lay directly above and below each other as they do when both arise from undisplaced midline structures We wanted our operators to elicit the most persistent maximal amplitude echoes no matter where they lay along the scan only thus did we feel we could make the test truly objective and free from observer bias Moreover when the instantaneous exposures were being made it is not always easy to display satisfactory echoes of sufficient amplitude from both sides simultaneously

Acknowledgements

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SUMMARY

An attempt has been made to design a technique for A scan echo-encephalography which is objective and reproducible and which provides an easily read graphic record This has been achieved by using time exposures to identify the maximal and most persistent echo which is considered the M echo The position of the M echo is then recorded with instantaneous exposures and transmission pulses are used to determine its position with relation to the theoretical midline The M echo however can only reliably be elicited from the midline structures in the region of the posterior margin of the third ventricle

ZUSAMMENFASSUNG

Es wurde versucht eine objektive wiederholbare und leicht lesbare Registriermethode fur die A Scan Echo encephalographie zu entwickeln Dies konnte bewirkt werden in dem man Zeitaufnahmen machte die das Maximalecho das am langsten andauerte registrierte dieses wird dann kurz als M-echo bezeichnet Die Lokalisation des M echos wird spater mit Momentaufnahmen festgehalten und man benutzt dann die Transmissionimpulse um dessen Lage in Bezug zur theoretischen Mittellinie zu ermitteln Ein gutes M echo wird jedoch nur von den in der Mitte liegenden Strukturen die hinter dem dritten Ventrikel liegen hervorgebracht

RÉSUMÉ

Les auteurs ont essayé de mettre au point une technique d écho-encéphalographie A qui soit objective reproductible et qui donne un enregistrement graphique facile a lire Ils y sont parvenus en utilisant des durees d exposition permettant d identifier l écho *maximal et le plus* persistant qui est considéré comme l écho M La position de l écho M est ensuite enregistree

par une exposition instantanée et on utilise des impulsions de transmission pour déterminer sa position par rapport à la ligne médiane théorique Ce n est cependant que dans la région de la partie postérieure du troisième ventricule que l on peut déduire surement l écho M des structures de la ligne médiane

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AUS DER NEUROCHIRURGISCHEN KLINIK DER UNIVERSITAT KOLN UND DEM MAX PLANCK INSTITUT FUR HIRNFORSCHUNG ABTEILUNG FUR TUMORFORSCHUNG UND EXPERIMENTELLE PATHOLOGIE (DIREKTOR PROFESSOR W TONNIS) KOLN, DEUTSCHLAND

HIRNDURCHBLUTUNGSMESSUNG MIT ISOTOPEN UND IHR KLINISCHER WERT

von

O WILCKE

Die bisher entwickelten Methoden zur Bestimmung der Hirndurchblutung mit Isotopen lassen sich in 2 Gruppen einteilen

1) In Methoden die eine quantitative Bestimmung des cerebralen Blutvolumens bezwecken

2) In Methoden zur qualitativen Bestimmung der Hirndurchblutung

Die quantitativen Methoden basieren auf dem Prinzip der Methode von KETY & SCHMIDT und ermoglichen durch den einfachen und schnelleren Nachweis der radioaktiven Isotope die Bestimmung des cerebralen Blutvolumens des Herzminutenvolumens und auch des Sauerstoffverbrauchs des Hirns (*NYLIN MUNCK LASSEN, HEDLUND u a*) *Die hierzu notwendige Punktion* der Carotiden und Venae jugulares stellt jedoch eine erhebliche Belastung fur den Patienten dar so dass die Methode zur klinischen Routineuntersuchung ungeeignet ist Bei den anderen quantitativen Isotopen Methoden (THOMPSON *OLDENDORF HORTEN*) werden nach Bestimmung des Gesamtblutvolumens aus dem Verlauf der uber dem Schadel registrierten Aktivitatskurven durch Bestimmung des Volumenindex Zahlenwerte gewonnen die auf das cerebrale



Abb 1 Apparat zur qualitativen Bestimmung der Hirndurchblutung

Blutvolumen schliessen lassen Alle diese Methoden sind mit erheblichem Zeitaufwand verbunden und haben eine gewisse Fehlerbreite, so dass sich nur aus dem Querschnitt einer grosseren Untersuchungsreihe Aussagen machen lassen Fur die klinischen Belange wichtige Aussagen uber die regionalen Zirkulationsverhältnisse oder die unterschiedliche Durchblutung beider Hirnhalften oder auch uber kurzfristige Veranderungen der Hirnzirkulation lassen sich mit diesen Methoden nicht machen

Eigene Methode

Zur schnellen klinischen Information uber die cerebralen Durchblutungsverhaltnisse haben wir eine qualitative Methode entwickelt, bei der in einem Arbeitsgang sowohl die Zirkulationszeit, als auch die Gesamtdurchblutung jeder Hirnhalfte bestimmt wird Wir verwenden 50—100 μc ^{131}J Hippuran und bestimmen nach Injektion in die Cubitalvene die Zirkulationszeit mit Hilfe von 2 Szintillationszahlern, die uber der Carotis und, tangential zum Schadel, uber dem Confluens sinuum angesetzt werden (Abb 1) Gleichzeitig wird mit 2 weiteren bifrontal aufgesetzten Szintillationszahlern der Durchfluss der Radioaktivitat durch jede Hirnhalfte gemessen Die besondere Anordnung der Zahler, sowie entsprechende Bleiabschirmungen und trapezformige Kollimatoren ermoglichen eine strenge Trennung beider Hirnhalften Durch die Verwendung von Einkanalanalysatoren wird durch Aus

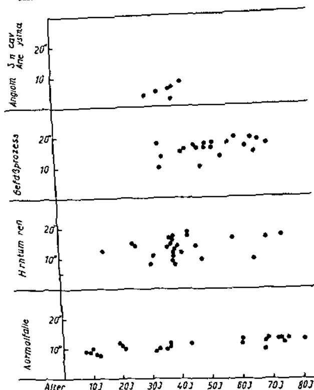


Abb 2 Zirkulationszeiten bei Normalfällen Hirntumoren arterioskle otischen Gefässprozessen und Angiomen oder Carotis Sinus cavernosus Aneurysmen

blendung des Gammaspektrums die Streustrahlung aus dem Korper unter druckt und nur die Direktstrahlung einer Hirnhalfte erfasst Die Registrierung erfolgt uber Vorverstarker und Ratemeter mit einem Vierfachschreiber Die Zeitkonstante der Ratemeter zur Bestimmung der Zirkulationszeit be tragt 0 3 sec die des Schreibers bis zum Vollausschlag 1 sec Um ein uber sichtliches Kurvenbild uber den Hemispharen zu erhalten hat sich hier die Ratemeter Einstellung auf eine Zeitkonstante von 1—3 sec als nutzlich er wiesen Die Untersuchung dauert wenige Minuten und kann leicht ambulant durchgefuhrt werden

Ergebnisse

Die Zirkulationszeit gemessen am Aktivitatsmaximum uber der Carotis bis zum Aktivitatsmaximum uber dem Confluens sinuum betragt bei dieser Messung (Abb 2) bei Normalpersonen 7—12 sec Bei Patienten mit Hirn

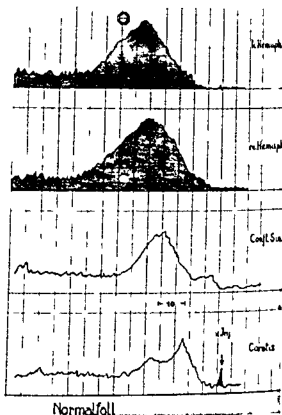


Abb. 3. Normalfall: = i.v. Injektion. Zirkulationszeit 10 sec. Gleicher Kurvenverlauf über der rechten und linken Hemisphäre

tumoren sind die Zirkulationszeiten deutlich verlängert und es wurden, besonders wenn Hirndruck bestand, Zeiten bis 23 sec gemessen. Auch bei Patienten mit klinisch nachgewiesenen, sklerotischen Gefässprozessen ist die Zirkulationszeit verlängert, während erwartungsgemäss bei Angiomen und Sinus cavernosus Aneurysmen die Zirkulationszeit verkürzt ist.

Im Normalfalle (Abb. 3) findet sich ein gleicher Kurvenverlauf über beiden Hemisphären sowie eine normale Zirkulationszeit von etwa 10 sec. Sowohl beim ersten Durchfluss der Radio-Aktivität durchs Hirn, als auch im weiteren Verlauf nach Gleichverteilung in der Blutbahn, finden sich über beiden Hemisphären gleich hohe Kurvenverläufe, die einer seitengleichen Verteilung der Aktivität entsprechen. Bei Hirntumoren finden sich meist Differenzen in der Durchblutung beider Hirnhälften (Abb. 4). Bei stark durchbluteten Tumoren, wie Meningiomen, bleibt auch dem ersten Durchfluss der Radio-Aktivität durchs Hirn die Aktivität über der Tumorseite höher. Die Zirkulationszeit ist bei Meningiomen häufig normal. Erst bei klinisch erkennbaren Hirndrucksymptomen ist die Zirkulationszeit verlängert. Bei Glioblastomen findet sich fast stets eine verlängerte Zirkulationszeit. Für gliomatose Tumoren ist die verlängerte Zirkulationszeit und das langsamere Absinken der Kurve

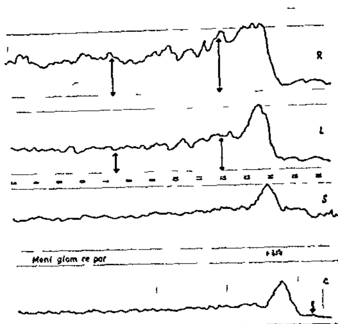


Abb 4 M nin iom echts p rietal Normale Z kulations e t (7 5 sec) Entspre hend dem Blut e chtum des Tumors ist d e Radio-Akt vitat uber der rechten H m spha e anhalt nd hoher als uber der l nken

uber der Tumorseite auf eine gleichbleibende Hohe typisch (Abb 5) Sehr charakteristisch ist das Bild bei sklerotischen Gefassprozessen (Abb 6) wo die verlangerte Zirkulationszeit mit nur geringen Ausschlagen uber beiden Hirnhalften stets die Diagnose ermoglicht Angiome sind durch eine verkurzte Zirkulationszeit und anhaltende Erhohung der Radio Aktivitat uber der Angiomseite gekennzeichnet Bei Carotis Sinus cavernosus Aneurysmen (Abb 7) zeigt die verkurzte Zirkulationszeit den arterio venosen Kurzschluss an Bleibt im weiteren Verlauf die Aktivitat uber beiden Hirnhalften gleich hoch, so ist darauf zu schliessen dass die gesunde Seite die Blutversorgung der Aneurysmaseite mit ubernimmt Anderenfalls bleibt die Aktivitat uber der Aneurysmaseite zunachst niedriger als uber der gesunden Seite Auch beim frischen Hirntrauma kann diese qualitative Hirndurchblutungsmessung wichtige diagnostische Hinweise geben (Abb 8) indem bei Vorliegen eines Hirnodems oder eines subduralen Hamatoms die betroffene Seite sich durch eine schlechtere Durchblutung und damit durch entsprechend flachen Kurvenverlauf darstellt

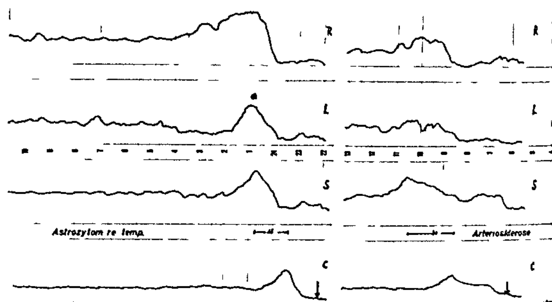


Abb 5 Astrocytom rechts temporal Verlangerte Zirkulationszeit (15 sec) Die Zirkulation ist auf der Tumorseite verlangsamt

Abb 6 Arteriosklerosis cerebri Verlangerte Zirkulationszeit (20 sec) Der niedrige Kurvenverlauf uber beiden Hemispharen zeigt die mangelhafte Durchblutung

Besprechung der Ergebnisse

Unter Verzicht auf quantitative Auswertungen ermoglicht diese qualitative Method zur Registrierung der cerebralen Zirkulationsverhaltnisse schnell und mit grosser Sicherheit diagnostische Aussagen Sie ist daher besonders fur die poliklinische Untersuchung eine wesentliche diagnostische Hilfe, zumal sie schnell auszufuhren und mit keiner Belastung fur den Patienten verbunden ist Aus der Kombination der Zirkulationszeit des Hirns und der kurvenmassig dargestellten Durchblutungsgrosse der beiden Hirnhalften ergeben sich wesentliche diagnostische Hinweise Eine verlangerte Zirkulationszeit weist stets auf eine mangelhafte Hirndurchblutung hin Diese kann entweder durch einen sklerotischen Gefassprozess oder durch eine intrakranielle Drucksteigerung bedingt sein Bei sklerotischen Gefassprozessen ermoglicht der flache, sehr charakteristische Kurvenverlauf uber den Hemispharen stets die Diagnose wahrend fur Hirntumoren die Differenz in der Durchblutung beider Hirnhalften und damit der unterschiedliche Kurvenverlauf typisch ist In gewissen Grenzen sind hierbei artdiagnostische Aussagen moglich Mit grosser Sicherheit weist eine verkurzte Zirkulationszeit auf einen arterio venosen Kurzschluss im Sinne eines Angioms oder eines Carotis Sinus cavernosus Aneurysmas hin Hier ist der uber den Hemispharen registrierte Kurvenverlauf

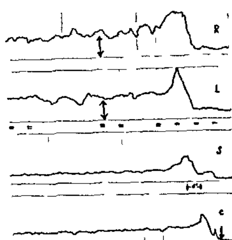


Abb 7 Carotis-Sinus-cavernosus Aneurysma links Verkurzte Zirkulationszeit (6 sec) Spitzwinkliger Kurvenverlauf uber der linken Hemisphare (arterio venoser Kurzschluss) Im weiteren Verlauf lasst die gleichhohe Radio-Aktivitat uber beiden Hemispharen darauf schliessen, dass die linke Hemisphare von der rechten Carotis mitversorgt wird

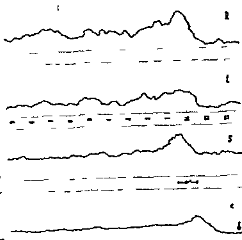


Abb 8 Subdurales Hamatom links Flacher Kurvenverlauf uber der Hamatomseite

fur jedes der beiden Krankheitsbilder typisch Der besondere Wert dieser Methode liegt damit neben der Tumordiagnostik vor allem in der Moglichkeit Gefassprozesse verschiedener Atiologie sicher zu erkennen und gegenuber Hirntumoren abzugrenzen Bei alteren Patienten fur die eine Carotis Angiographie gefahrvoll sein kann ist damit die Moglichkeit gegeben durch diese sehr einfache Untersuchung ein anschauliches Bild uber die Zirkulationsverhaltnisse des Hirns zu gewinnen

ZUSAMMENFASSUNG

Es wird eine Methode beschrieben bei der nach i v Injektion von wenigen μC eines radioaktiven Stoffes in einem Untersuchungsgang sowohl die Zirkulationszeit des Hirns als auch die qualitative Durchblutung beider Hirnhalften registriert wird An Hand von Beispielen werden die diagnostischen Moglichkeiten zur Erkennung von Hirntumoren und cerebralen Gefassprozessen verschiedenen Ursprungs dargestellt.

SUMMARY

The intravenous injection of a few millicuries of a radioactive substance makes it possible to assess simultaneously the circulation time of the brain as well as the relative circulation in either hemisphere Examples are given to demonstrate the diagnostic possibilities in cerebral tumours and in vascular conditions of varying origin

RÉSUMÉ

Description d'une méthode permettant après injection intraveineuse de quelques µCi d'un corps radioactif de déterminer en une seule séance le temps de circulation cérébrale et la qualité de l'irrigation des deux moitiés du cerveau. Des exemples illustrent la possibilité de diagnostiquer des tumeurs cérébrales et des processus vasculaires cérébraux d'origines diverses.

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THERMOGRAPHY IN THE DIAGNOSIS OF CEREBROVASCULAR OCCLUSIVE DISEASE

by

ERNEST H WOOD and RICHARD P HILL

Thermography is a relatively new medical procedure used to record the radiant heat emitted by the human skin A thermogram is a graphic recording of spontaneous infrared radiation that is obtained by scanning the skin surface Because heat emission of the body is automatic and the thermograph provides an atraumatic means of collecting heat for measurement the method constitutes a simple painless and harmless technique for determining the skin temperature and indirectly the cutaneous blood supply

Previous clinical uses of thermography have been concerned principally with the detection of increased skin temperatures Such abnormal radiant emissions have been found to occur with superficial neoplasms (WILLIAMS et coll 1961 BARNES & GERSHON COHEN 1963) some deep tumors (BARNES & GERSHON COHEN 1963) infections (WILLIAMS et coll 1961) over the sites of placental implantation (JOHNSON 1964) and in connection with various other conditions associated with increased blood supply to the skin Decreased radiant heat emissions have been shown to occur with impaired blood flow in the extremities (BARNES 1963) Only recently have alterations in the heat of



Fig 1 Direct facial thermography Patient seated in a comfortable chair and head immobilized The motor driven heat detecting device is directed toward the patient s head and the upper portion of the face is scanned automatically On table at left are accessories including a calibrated heat reference source (front) a manual bolometer (middle central and middle right) a thermal resistor (middle left) a semiquantitative graphic recorder of thermographic scanning data (rear)

the skin of the forehead been correlated with changes in cerebral circulation (Wood 1964)

It is the purpose of this paper to describe the practical methods that have been found most useful in applying thermography to clinical problems and to review the anatomic basis for its effectiveness Other aims are to assess the reliability of thermography as a means of surveying patients for the presence or absence of carotid artery disease, to compare the method with other accepted diagnostic procedures, and to suggest further clinical investigations for the evaluation and utilization of thermal data

General considerations

Thermography makes use of a high resolution scanning device (Fig 1) that records skin temperature information and presents the data photographically

The final products of thermography are a print and a negative that are available for immediate inspection through use of the Polaroid method The thermogram is a composite dark (cool) and light (warm) image formed by parallel lines each of which comprises approximately 350 point recording of thermal data (Fig 2)

Technically thermography is carried out simply and without preparation of the patient except for exposure of the part to be examined to cool dry air in a draft free room The ambient temperature should be maintained between 70 and 72 F (or approximately 21 and 22 C) Exposure of the skin for 10 to 20 minutes under these standard conditions serves to



Fig 2 No nal the mogr n Inf ared adiat on spontaneously em tted by sk n of upper face is reco ded and presented photog aphically as a light (wa m) and dark (cool) patt n The no e cheeks and avascular corneas of *the eyes are* ool as are the ha r insulated eyebrow eyelash and scalp areas The cal brated heat refe c ice ources at top of figure represent from the eade s left app oximately 98 6 95 5 93 92 and 90 5 degrees Fahrenheit (37 35 3 33 9 33 3 and 32 5 deg ees Cent g ade)

remove persp ration and otherwise create stable conditions to assure accurate measurement of cutaneo s infrared emissions Bedridden patients and others who cannot cooperate for direct scann ng as shown in Fig 1 can be examined in the horizontal position through the use of a front coated heat reflecting mirror

In the average cas symmetry or asymmetry of the heat emission patterns of the two sides of the forehead will be clearly man fested under the standard conditions described above In order to assure the demonstration of *minor* changes two primary thermograms after simple air co ling usually are made Each *tracing* is taken at an instrument etting of inter mediate sensitivity The brightness of the li ht *source* is varied for each primary examination to provide one l ght and one dark scan a meter on the thermograph denotes during canning what degree of photographic change *can* be expected

Thermo rams can be made with *many* different combinations of sensitivity and brightness as indications warrant In the present study *additional* thermograms have been made to determ ne the rate of ski i heat recovery after cooling to subambient levels Simple cold comp esses applied to the forehead constitute one of a variety of atisfactory methods of produc ng further cool ng of the skin The forehead *temperature* is evenly reduced five degrees below the average air-cooled primary reading (*usually* to about 88 F or 31 C) A hand held infra ed rad ometer or bolometer (F g 1) *or* the thermograph itself may be used to make certain that th secondary wet cooled forehead temperatures are the same on the two sides With the thermo raph then directed only towards the orbital and supraorbital reg ons re

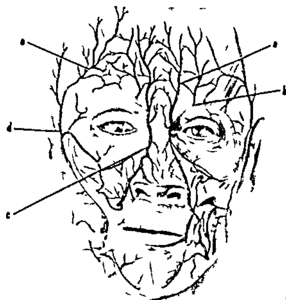


Fig 3 Superficial dissection of face Arterial vascular supply of soft tissues is from both internal carotid and external carotid systems While the latter is by far larger the medial supraorbital areas are supplied by the frontal (a) and supraorbital (b) branches of the ophthalmic artery Although anastomoses are present between the two sides between the frontal and angular (c) arteries and between the supraorbital artery and the frontal branches (e) of the superficial temporal artery (d) the temperature of the forehead is basically related to the ophthalmic artery flow on each side

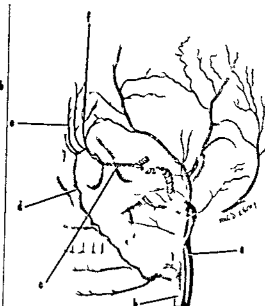


Fig 4 External and internal carotid system in relation to bony landmarks The extracranial extensions of the frontal (e) and supraorbital (f) arteries over the superior rim of the orbit are shown together with their deeper relationships to the ophthalmic artery (c) and the carotid system As an early large branch of the internal carotid artery (a) the ophthalmic artery is primarily dependent for its blood flow on the parent vessel In the presence of occlusion of the internal carotid artery the ophthalmic frontal and supraorbital arterial flow is reduced Collateral circulation superficially is through frontal anastomoses with the angular artery (d) a branch of the external carotid artery (b) and through supraorbital anastomoses with the superficial temporal artery profoundly the main collateral circulation is from the internal maxillary artery to the ophthalmic artery

scanning is carried out continuously (usually for 20 minutes) until heat emission has returned to the primary (air cooled) level on one or both sides In the present series no patient with an entirely normal primary thermogram has been shown to have abnormal findings after secondary wet cooling In occasional cases however secondary wet cooling has demonstrated not only delayed recovery of skin heat on the side of deficient circulation but also has made more readily discernible the insufficiency patterns described below

Normal facial thermograms vary according to fixed heat emission patterns The nose cheeks ears and the avascular corneas of the eyes are cool as are the hair insulated eyebrow eyelash and scalp areas The anterior portion of the forehead is warm heat normally is trapped by folds at the canthi and along the free margins of the eyelids Essentially symmetrical facial thermograms were found almost without exception in examining large numbers of healthy individuals of all ages

Anatomically the medial supraorbital integument is supplied almost exclusively by branches of the internal carotid artery (Fig 3) The frontal and supraorbital arteries are terminal extensions of the ophthalmic artery the latter being the first sizable branch of the internal carotid artery (Fig 4) The fact that the integumentary and anterior ocular branches of the ophthalmic artery provide the only surface display of the internal carotid artery constitutes the basis for the facial thermogram being an index of the blood flow through the carotid artery

The anterior ocular branches of the ophthalmic artery also may reflect carotid artery blood flow The inner canthus is supplied by branches of the medial palpebral and dorsal nasal arteries The anterior ciliary arteries and a branch of the supraorbital artery also contribute warmth to the medial canthus In contrast to the medial supraorbital integument which is supplied almost entirely by the internal carotid artery the medial palpebral commissure is also reached by the terminal angular branch of the external carotid artery Because of the dual blood supply the inner canthus does not provide an index of internal carotid artery blood flow as often as the supraorbital skin in occasional cases however the asymmetry of infrared radiation from the medial canthi and exposed surfaces of the globes is quite striking

An abnormal facial thermogram develops most frequently when there is asymmetrical radiant heat emission from the two medial supraorbital portions of the forehead owing to a deficient cutaneous blood supply which in turn is secondary to impaired carotid artery blood flow (Fig 5) In support of this anatomic explanation of the thermographic phenomena are changes that can be induced by vasal compression Mechanical compression of the common carotid or internal carotid artery in young healthy subjects will produce a thermographic pattern identical to that found following surgical ligation or in patients with atheromatous occlusion In addition compression of the frontal and supraorbital arteries against the bony rim of the orbit will produce forehead patterns similar to those caused by carotid occlusion

Material

The present investigation is based on the analysis of the thermograms and case records of a large number of patients with cerebrovascular occlusive disease in whom the anatomic nature of the pathologic process was established by angiography operation or necropsy In addition attention has been given to the thermographic changes associated with generalized vasal alterations salient anatomic variations and severe local abnormalities of circulatory physiology caused by non occlusive vascular lesions The most significant thermographic findings have occurred in patients with extra cranial lesions of the carotid arteries many of which are amenable to surgical treatment

Unilateral occlusion of the internal carotid artery was the most frequently encountered lesion producing an abnormal thermogram among all of the cases that have been studied (Fig 6) As noted above patients who had undergone surgical ligation of the internal carotid artery or common carotid artery exhibited parallel thermographic changes Patients with external carotid artery ligation had essentially normal thermograms Unilateral atherosclerotic occlusion

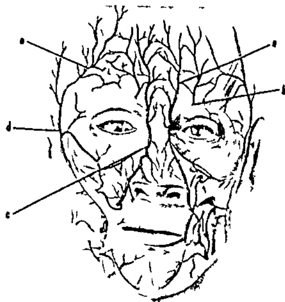


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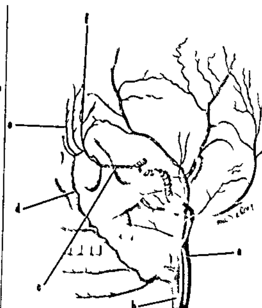


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Fig 6 Left internal carotid artery occlusion The thermogram discloses an area of cool supraorbital skin on the left side Angiography disclosed complete occlusion of the internal carotid artery at its origin

atic role of the circle of Willis in its attempt to preserve cerebral circulation lling of both middle and both anterior cerebral arteries from the stenotic de usually can be demonstrated at angiography Associated with the cerebral emand on the still patent internal carotid artery is a reduction of outward lood flow in (or steal from) the ophthalmic artery The circumstances are omewhat analogous to the steal (or bypass) phenomenon associated with n arteriovenous fistula in the cavernous sinus or a large angioma of the brain ith an arteriovenous shunt (Fig 7)

In patients with bilateral asymmetrical atherosclerosis who have had surgi al restoration of the carotid lumen to normal size on the stenotic side, the lark supraorbital patch associated with the stenosis disappears, follow up ngiography indicates that the repaired artery then is capable of supplying ts own ophthalmic branch as well as the opposite cerebral hemisphere Inasmuch s the majority of such patients present themselves with symptoms and neuro ogical signs referable only to the fully occluded side a thermographic change contralateral to clinical manifestations should lead to a diagnosis of bilateral carotid insufficiency with the objective of instituting treatment to improve circulation on the still patent side Thus far an opportunity to perform thermography in a patient with complete obstruction of both internal carotid arteries has not presented itself

Proximally stenosis or occlusion of the orifice of the common carotid artery by atherosclerosis dissecting aortic aneurysm or other diseases have been



Fig ? Right sided carotid occlusion Right supraorbital area darkened in territory supplied by frontal and supraorbital arteries owing to complete obstruction of the internal carotid artery with resultant reduced vascular supply to the surface Calibrated reference sources and hand bolometer readings disclosed that on the normal left side the skin temperature was 94 F (34 4 C) while on the abnormal right side it was 91° F (3? 8 C)

or stenosis of the common or internal carotid artery has produced, without exception, an ipsilateral patch of cool supraorbital skin demonstrable in the thermogram Patients with marked carotid artery kinking and with sizable atherosclerotic plaques that were symptom producing exhibited similar changes Since beginning this study, we have not encountered any patients with normal thermograms who later were found to have carotid artery occlusion or stenosis by angiography or at operation

It has also been shown that patients who have had a successful surgical carotid artery repair with re establishment of good blood flow, as shown by angiography, have developed a normal thermogram If attempted surgical restoration of the vessel lumen fails, or if a strong blood flow is not maintained postoperatively, the thermogram will remain abnormal There has been insufficient experience with patients receiving anticoagulants to state whether thermography is useful in evaluating the effectiveness of such medical treatment

Bilateral asymmetrical carotid atherosclerosis causes more complex changes in the thermogram than occur with a unilateral lesion In patients with occlusion on one side and carotid stenosis on the other the cooler supraorbital skin at thermography is found on the side of the stenosis The best explanation appears to be twofold First, the occlusive lesion is more mature, and well developed collateral circulation often is found for the ophthalmic artery and its branches through the facial soft tissue anastomoses Second, is the homeo



Fig 6 Left nt rnal carotid artery occlu on The thermogram discloses an a ea of cool suprao b tal skin on the left side Angiogr phy disclosed complete occlus o i of the nternal carotid artery at its orig n

static role of the circle of Willis in its attempt to preserve cerebral circulation filling of both middle and both anterior cerebral arteries from the stenotic side usu lly can be demonstrated at angio raphy Associated with the cerebral demand on the still patent internal carotid artery is a reduction of outward blood flow in (or steal from) the ophthalmic artery The circumstances are somewhat analogous to the steal (or bypass) phenomenon associated with an arteriovenous fistula in the cavernous sinus or a large angioma of the brain with an arteriovenous shunt (Fig 7)

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Proximally stenosis or occlusion of the orifice of the common carotid artery by atherosclerosis dissecting aortic aneurysm or other diseases have been



Fig 7 Arteriovenous malformation of left cerebral hemisphere The thermogram (a) discloses a large area of forehead coolness in left medial supraorbital region Left orbit and anterior convexity of the globe are cooler than the right The angiogram (b) reveals enlargement of internal carotid and its middle cerebral extension supplying a large angioma of the convexity which exhibits shunting of contrast material into the venous system No filling of left ophthalmic artery or anterior cerebral artery

associated with abnormal facial thermograms In some instances, corrective intrathoracic surgical procedures have been undertaken

Distally abnormal thermograms have not been found in association with occlusive lesions above the clinoid level Thus, occlusion of the carotid siphon, of the middle cerebral artery or of various cerebral branch arteries have not caused thermographic changes

Generalized cerebral atherosclerosis and scattered small plaques have not been found responsible for specific thermographic patterns although an overall coolness of skin temperature often is found in bolometer readings The generalized vasal alterations produced by fever, coma or the lack of standard conditions for the examination frequently obscure a local vascular disorder Thermographic studies after the inhalation of carbon dioxide or oxygen and studies involving the pharmacologic effects of a host of drugs are under way, but are beyond the scope of this paper

Comment

It is apparent from the foregoing data that thermography provides a ready means of evaluating carotid artery circulation by assessing the blood flow in

the small group of branches that constitute the only extension of the internal carotid artery to the body surface. Thermography plays its chief role in detecting lesions that produce a reduction in flow in the internal carotid artery by narrowing of the common carotid at its orifice or by compromising the lumen of the internal carotid artery *in the neck*. The abnormal thermogram is most often associated, therefore, with lesions in locations accessible for surgical correction. Thermography, as described in this paper, is *primarily a technique* for the analysis of carotid blood flow and might more properly be called *carotid thermography*.

Semiquantitative tracings can be made of the multitude of bolometric readings executed by the thermograph (WOOD 1964). The value of precise quantitative heat determinations separate from the photographic display is not yet clear, and more experience will be required to find the proper niche for such data. The *postoperative studies* of pressure and flow, and of angiographic changes after carotid obstruction, suggest that there is so much variation from case to case that quantitative readings and clinical effects may be very difficult to reconcile (ODOM et coll. 1962). It is necessary to keep in mind that the vascular supply of the skin provides only one parameter for deducing the complex manifestations of carotid disease (ALLEN & MUSTIAN 1962).

Calibrated reference sources have been used to collect quantitative data 1) at the time of clinical thermography (Figs. 1 and 2), 2) in conjunction with infrared radiometer readings taken directly from the facial skin, and 3) with clinical thermopiles and thermal resistors. The facial skin temperatures of many hundreds of normal individuals and patients have been determined in these ways. On the average, *the temperature of the medial integument of* the forehead is 93.5° F (34.2° C). *Occasionally normal individuals are found* with skin temperatures 2° F (1.1° C) above, and as much as 3° F (1.7° C) below the average level; greater deviations are rare. Differences between the two sides usually are small, as evidenced by thermograms (Fig. 2). On the other hand, the values obtained by attaching thermopiles or thermal resistors to the skin, or by *hand held bolometers*, are not as reliable as those of the thermograph in detecting asymmetry because the sensitivity and resolution of the more simple instruments are lower. The average measured variation between right and left, using the manual bolometer, was 0.6° F (0.3° C) in the large series studied. Manual bolometer temperature differences of 1.8° F (1.0° C) were found to be *significant* in all cases. Although it is common for patients with carotid insufficiency to exhibit a variation of as much as 3° F (1.7° C) and occasionally more between the two sides of the forehead, nevertheless, it is doubtful that ordinary thermal resistors and simple bolometers can substitute for the thermograph in clinical work. The delicate display

provided by the thermograph allows a visual comparison of the two sides and the detection of subtle relative changes that cannot be approached by other instruments. Although no normal thermogram has been found in the presence of carotid occlusion or symptomatic stenosis, it is to be expected that exceptions will be encountered with further experience. The rare cases with falsely positive thermograms were benefited by definitive angiographic diagnosis and in each instance angiography provided a clear explanation of the thermographic changes (Fig. 7).

At the time of thermography, each patient had a thorough clinical examination by a qualified neurologist. Procedures popular in the past to help determine the presence or absence of carotid disease also were carried out, including ophthalmodynamometry, the clinical assessment of pulsations and any bruits detected, and radioactive isotope studies in selected cases. Thermography was more reliable by far than the other procedures as a method of surveying patients for the presence or absence of carotid disease. Personal experience with carotid compression tests has been limited since the opinion prevailed among the physicians who attended these patients that compression maneuvers carry some risk; thermography, however, was more successful in the cases described here than carotid compression in the hands of others who have described their experiences in the literature (TOOLE & BEVILACQUA 1963).

SUMMARY

Thermography is a superior method of surveying patients for the presence or absence of carotid artery insufficiency; the procedure appears to be more reliable than isotope circulation studies, ophthalmodynamometry, the carotid compression test (with or without electroencephalography) and the clinical evaluation of carotid pulses and bruits. Thermography has been used successfully to aid in the selection of patients requiring angiography and to evaluate the effectiveness of therapy. Reversal of the thermographic patterns after treatment serves as an index of the effectiveness of therapy.

ZUSAMMENFASSUNG

Thermographie ist eine gute Methode um die Anwesenheit oder Abwesenheit von Carotisinsuffizienz zu zeigen; sie scheint zuverlässiger als Isotopzirkulationsstudien, Ophthalmodynamomessungen, Carotiskompressionsteste (mit oder ohne Elektroenzephalographie) und als klinische Auswertung des Carotispulses und des Carotisgeräusches zu sein. Thermographie ist mit Erfolg bei der Auswahl von Patienten die Angiographie erfordern und um die Effektivität der Behandlung auszuwerten verwendet worden. Eine thermographisch registrierte Verbesserung nach der Behandlung dient als ein Effektivitätstest der Behandlung.

RESUME

La thermographie est la meilleure methode de dépistage de l insuffisance carotidienne elle parait plus fidele que les études isotopiques de circulation l ophtalmodynamométrie l epreuve de compression carotidienne (avec ou sans électro-encéphalographie) et que l étude clinique du pouls et des bruits carotidiens La thermographie a été utilisée avec succes pour contribuer a poser les indications de l angiographie et pour juger l efficacité des traitements L amelioration des thermogrammes apres traitement sert de test de l efficacité des traitements

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GAMMA ENCEPHALOGRAMS IN EXTRACEREBRAL HEMATOMAS

by

L ZINGESSER, S MANDELL and M SCHECHTER

The potentialities of gamma encephalography are still being explored as work progresses in pharmacologic and electronic spheres relating to scanning and as clinical experience accumulates The purpose of this paper is to report our experience with the use of gamma encephalography (rectilinear scanning) in the evaluation of patients who have sustained head trauma In previous scanning series extracerebral hematomas have been labelled only false positives, meaning that they presented on radioactive brain scans as lesions that might be confused with neoplasms Other workers have dealt specifically with extracerebral hematomas The ability to localize extracerebral hematomas depends on a difference between count rates from the lesion itself and adjacent areas This is a function of both the isotope employed and the chemical and physical properties of the labelled compound Radioactive iodine labelled compounds such as diiodofluorescein and serum albumin do get into subdural fluid though usually there is less radioactivity in this compartment than in the peripheral venous blood (MOORE 1958 DUNBAR et coll 1954, FEINDEL et coll 1963) Scanning with ^{64}Cu has seldom demonstrated an extracerebral hematoma ^{74}As by virtue of its concentration in subdural membrane enables demonstration of subdural hematomas (SWEET et coll 1961, MEALY 1963) When radioactive mercury labelled chlormerodrin is used, epidural and subdural hematomas appear on the brain scan (in the

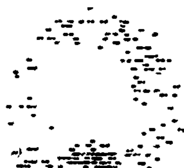


Fig. 1. A-p. scan of a patient with bilateral chronic subdural hematomas.

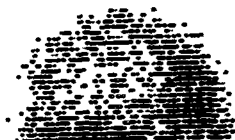


Fig. 2. A-p. scan of patient with bilateral subacute subdural hematomas. Left subdural appears thicker than right but is thinner in reality.

frontal projection) as an increase in the normal vascular rim. Radioactive mercury labelled chlormerodrin has shown the best results in the demonstration of extracerebral hematomas to date as has been noted by McGinnis et coll. (1963) and by Mealy (1963) among others.

A tabulated summary of the literature on the demonstration of extracerebral hematomas using radioactive isotopes is presented below.

Our experience with the interpretation of gamma encephalograms using radioactive mercury is derived from two sources: (1) scans of patients who have sustained trauma and those who have not, and (2) comparison of count

Year	Author	Diagnostic agent	Lesions	Results
1951	Ashkenazy et coll.	Diiodofluorescein	8 chronic subdurals	Little or no localization
1952	Peyton et coll.	Diiodofluorescein	1 chronic subdural	Localized
1953	Moore et coll.	RISA	several subdural hem.	Only one localized due to isotope in adjacent edematous brain
1954	Dunbar & Ray	RISA	4 unilateral subdurals	Localized due to leakage into adjacent brain
1957	Rhodes & Nowlis	RISA	1 patient with bilateral subdurals	Not localized
1961	Feindel et coll.	RISA	3 subdurals	*Localized*
1961	Sweet et coll.	Cu	1 chr. epidural	Not localized
		As	3 subdurals	Not localized
1962	Brinkman et coll.	Hg	8 subdurals	7 localized
			2 subdurals	Localized
1963	Mealy	RISA	Localization after injection into subdural cavity	
1963	Mealy	²⁰³Hg	3 subdurals	Localized
1963	McGinnis et coll.	²⁰³Hg	19 subdural	Localized

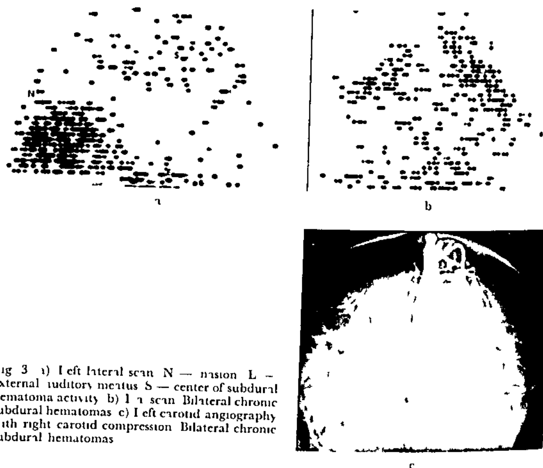


Fig 3 a) Left lateral scan N — nasion L — external auditory meatus S — center of subdural hematoma activity b) L a scan Bilateral chronic subdural hematomas c) Left carotid angiography with right carotid compression Bilateral chronic subdural hematomas

rates of samples of extracerebral hematomas collected at the time of surgery with peripheral venous blood

There are no false negatives in our scanning series, i e none of the cases which we are asked to scan turned out to have an extracerebral hematoma when the scan was entirely negative

Six patients with extracerebral hematomas had positive scans In the first case (Fig 1) scanning demonstrated the presence of bilateral, chronic subdural hematomas In the second case (Fig 2) scanning demonstrated bilateral subacute subdural hematomas, but although the a p scan suggested that the subdural hematoma on the left was thicker than that on the right, in actuality the right sided collection was thicker Left sided periorbital ecchymoses probably accounted for the discrepancy In the third case (Fig 3) the a p scan was entirely negative Only the lateral and p a scans indicated the presence of bilateral chronic subdural hematomas which were posteriorly situated In the next case (Fig 4), a patient with bilateral subacute subdural hematomas in which the left subdural hematoma was thicker than the one on the right,

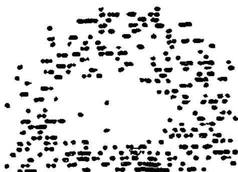
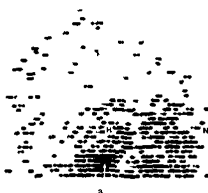
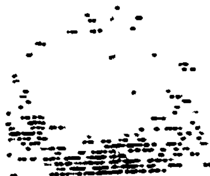


Fig 4 A p scan of a patient with bilateral subdural hematomas The one on the right is overshadowed by the left sided subdural



a



b

Fig 5 a) Right lateral scan of a patient with an epidural hematoma adjacent to the temporal lobe N — nasion white arrow — external auditory meatus H — center of the hematoma b) A p scan of the patient with the right sided epidural hematoma

scanning clearly demonstrated the left subdural hematoma The one on the right is not as obvious The interpretation of the scan of a patient with bilateral subdural hematomas is often difficult because of the fact that comparison of the two sides is crucial in evaluation of the a p and p a scan and one side may overlie the other In the next case (Fig 5) scanning demonstrated what angiographically seems to be an epidural hematoma There is no surgical confirmation of this lesion No operation was performed because the patient was doing well clinically In the next case (Fig 6) scanning demonstrated a subgaleal hematoma This was clinically evident although it had reached maximum size some weeks before and was regressing in size Angiography and encephalography were entirely negative

Our false positive cases were as follows (1) bilateral heavy vascular rim (2) aneurysm of left internal carotid artery (3) peripheral infarct, and

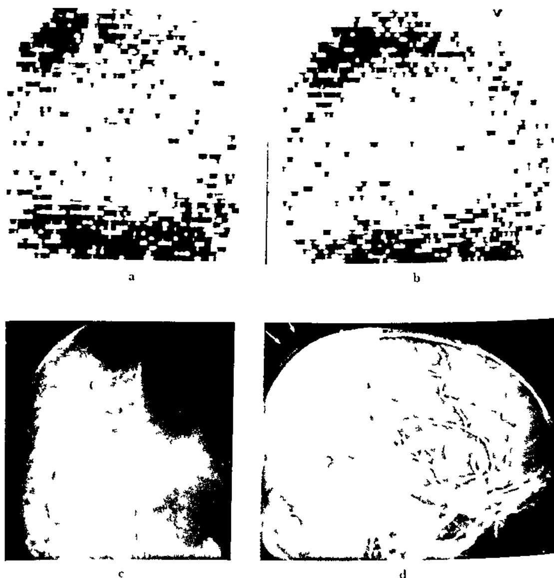


Fig 6 a) A p scan of a patient with a subgaleal hematoma in the right parietal area b) Right lateral scan of the patient with the subgaleal hematoma c) Right carotid angiogram No intracranial hematoma d) Lateral view right carotid angiogram The subgaleal hematoma is indicated by the arrows

(4) peripheral metastatic tumor We have learned there are certain pitfalls in the diagnosis of extracerebral hematomas using scanning with radioactive mercury Injury to the oft tissues — ecchymoses of the face and subgaleal hematomas — lead to an abnormal concentration of radioactive isotopes in the e areas Paget s disease and renal disease are often associated with a heavy concentration of activity around the periphery of the brain

scan and for this reason they enter into the differential diagnosis of bilateral subdural hematomas Infarcts and tumours may simulate subdural hematomas if they are peripherally located Our first false positive case (Fig 7) is such only in the sense that the $2^1/_2$ hour scan showed a heavy vascular rim bilaterally when there was no history of renal disease or Paget s disease The scan performed after 24 hours no longer showed this heavy vascular rim so we dismissed the diagnosis of bilateral extracerebral hematomas The 24 hour scan was performed because we had realized at this time that the collections which were extracerebral would be seen better after 24 hours since the blood was being cleared of mercury while the extracerebral collections retained a relatively high radioactive mercury content We have no good explanation for the next false positive scan (Fig 8) where the pathology was an aneurysm of the left internal carotid artery Scanning suggested a right subdural hematoma Perhaps spasm on the left with diminished blood flow there reduced the normal vascular rim there, leading to misinterpretation of a normal vascular rim on the right side as a subdural hematoma Spasm was not present angiographically however The patient at autopsy had no evidence of blood either in the subarachnoid or subdural spaces on the right The next two patients had scans which suggested subdural hematomas One had an infarct and one had a peripherally situated tumor

We have alluded to the fact that we have counted samples of extracerebral collections removed at the time of operation and compared the count rate to peripheral venous blood removed at the same time The results are summarized below

It appears as if the ratio of counts in extracerebral hematoma to counts in peripheral venous blood increases as the time interval increases between the administration of the isotope and the operative procedure This means then that while blood is being cleared of the radioactive isotope the extra

Patient	Radioisotope	Time interval between administration and operation	Ratio in cts/min/ml between hematoma and peripheral venous blood as percentage	Lesion
G	Hg	6 days	Left 141 Right 105	Bilateral chronic subdural
I	Hg	20 hours	Left 435 Right 457	Bilateral chronic subdural
D	Hg	10 hours	117	Chronic subdural
O	Hg	6 hours	9	Subacute subdural
	Cr (tagged R B C)	4 days	2 9	
S	Hg	4 / hours	7	Acute subdural
H	Hg	3 hours	9	Acute subdural
B	Hg	2 / hours	5	Acute subdural
R	Hg	1 hour	10	Acute subdural

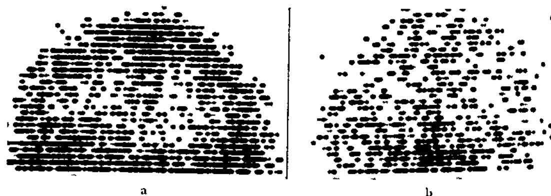


Fig. 7. a) A-p. brain scan performed at $2^1/_2$ hours in a patient with no Paget's disease, renal disease or extracerebral hematomas. The vascular rim is exceptionally prominent. b) A-p. scan after 24 hours: vascular rim no longer prominent.

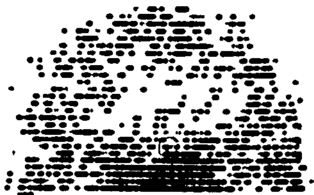


Fig. 8. A-p. scan of a patient with an infraclinoid internal carotid aneurysm on the left. The vascular rim is more prominent on the right than the left.

cerebral hematoma is being cleared much more slowly. Case 4 (labelled 0) is of particular interest as this patient received ^{51}Cr labelled red cells about four days before receiving radioactive mercury. Note that the differential counting indicated that there seemed to be some leakage of fresh blood into the subacute subdural hematoma, but that there was much more radioactive mercury present in the subdural collection than radioactive chromium.

An inquiry into the pathologic mechanisms involved in the production of the positive scan in patients with extracerebral hematomas is the next step in our discussion. When a patient is given a diagnostic dose of radioactive mercury approximately 80 % of the radioactive mercury that is intravascular is found in the plasma. Roughly 20 % is bound to red cells, bound meaning

that the mercury cannot be washed off with saline About 98 % of the mercury in plasma is complexed with protein Using an electrophoretic technique we have found that approximately 11 % of the protein bound mercury in plasma is complexed with albumin 5 % with alpha one globulin 67 % with alpha two globulin 13 % with beta globulin and 4 % with gamma globulin Other workers have indicated that mercury is attached to the sulfhydryl groups of protein molecules

Chronic subdural hematomas are richer in protein especially albumin (CITLIN 1955) than plasma The membranes of chronic subdural hematomas contain blood vessels Physical laws govern the diffusion of mercury through the semipermeable membranes of the subdural hematomas and while the plasma level of radioactive mercury is regressing a relative increase in the amount of radioactive mercury within the subdural collection is noted

The vessel wall is the only barrier in the acute subdural hematoma yet enough radioactive mercury gets into the acute extracerebral hematoma to increase the vascular rim or cap of the rectilinear scan enabling diagnosis of this condition Our patients with acute extracerebral hematomas came to surgery much sooner than those with chronic extracerebral hematomas yet significant count rates were found within these acute subdural collections due to both diffusion and probably to continued bleeding Further work involving the administration of both chromium tagged red cells and radioactive mercury needs to be done to support this last contention

Acknowledgement

This work was supported in part by a Special Traineeship (B T 937) from the National Institute of Neurologic Diseases and Blindness Public Health Service

SUMMARY

Rectilinear scanning using radioactive mercury labelled chlormerodrin may safely be used as a screening device in the evaluation of patients with a history of trauma There are no false negative scans in our series False positive scans were encountered and the causes are discussed Use of a technique involving the administration of ^{51}Cr labelled red cells in addition to chlormerodrin labelled with radioactive mercury may be used to elucidate the pathogenesis of subdural hematomas since the count rates of the two isotopes in the extracerebral collection can be differentiated

ZUSAMMENFASSUNG

Geradlinige Szintigraphie mit radioaktivem Quecksilber gemerktem Chlormerodrin kann als primäre Untersuchung von Patienten mit Trauma Anamnese verwendet werden Unsere Serie umfasst keine falschen negativen Szintigramme jedoch wurden falsche positive gefunden Die Ursachen hierfür werden besprochen Es können Cr gemerkte roten Zellen

zusätzlich zu radioaktivem Quecksilber gemerktem Chlormerodrin verabreicht werden, um die Pathogenese der subduralen Hämatome zu beleuchten, da die Zählgeschwindigkeit dieser zwei Isotopen in der extracerebralen Ansammlung differenziert werden können.

RÉSUMÉ

La scintigraphie rectiligne utilisant la Chlormerodrin marquée au mercure radioactif peut être employée sans danger comme méthode de dépistage chez les malades ayant des antécédents traumatiques. Il n'y a pas de scintigraphies faussement négatives dans notre série. Il y a des scintigraphies faussement positives dont les auteurs examinent les causes. Pour élucider la pathogénie des hématomes sous duraux, on peut associer à la Chlormerodrin marquée au mercure radioactif l'administration de globules rouges marqués au ^{51}Cr car on peut distinguer le comptage des deux isotopes dans la collection extra cérébrale.

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EXPERIENCES WITH SH 617 L MYELOGRAPHY

by

A Baciocco A Galluzzo and S Sassaroli

After the introduction of lumbar myelography with water soluble contrast media whose usefulness has been widely recognized, it seemed desirable that a contrast medium possessing similar properties for total myelography should be evolved

Experimental attempts (Funkquist & Obel 1960, Sassaroli & Baciocco 1961) with the aim of evolving such a contrast medium have not been successful We can therefore understand the interest aroused by the introduction of the SH 617 L medium which has been referred to as resorbable and suitable for cisternal and lumbar introduction We have had an opportunity to try SH 617 L in a series of eighteen myelographies using both techniques Our conclusions from the use of this contrast medium may be stated in the following

In the amounts of SH 617 L suggested by the producer the absorption of roentgen rays by the medium is clearly lower if compared with pantopaque and kindred contrast media including the water soluble ones The best results are achieved when the medium is introduced as close as possible to the lesion

No symptoms were noted during or immediately after the examination After 8 to 10 hours all the patients showed an irritative meningeal reaction with fever lasting a few days Because of this the neurologist could always determine which contrast medium had been used Invariably the cerebrospinal

zusätzlich zu radioaktivem Quecksilber gemerktem Chlormerodrin verabreicht werden um die Pathogenese der subduralen Hämatome zu beleuchten da die Zählgeschwindigkeit dieser zwei Isotopen in der extracerebralen Ansammlung differenziert werden können

RÉSUMÉ

La scintigraphie rectiligne utilisant la Chlormerodrin marquée au mercure radioactif peut être employée sans danger comme méthode de dépistage chez les malades ayant des antécédents traumatiques Il n'y a pas de scintigraphies faussement negatives dans notre série Il y a des scintigraphies faussement positives dont les auteurs examinent les causes. Pour élucider la pathogénie des hématomes sous-duraux on peut associer à la Chlormerodrin marquée au mercure radioactif l administration de globules rouges marqués au ⁵¹Cr car on peut distinguer le comptage des deux isotopes dans la collection extra cérébrale

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ZUSAMMENFASSUNG

Ein gewisse Anzahl von myelographischen Untersuchungen wurden mit einem neuen resorbierbaren Kontrastmittel bezeichnet SH-617 L ausgeführt Das neue Kontrastmittel bietet zwar einige Vorteile ist jedoch anderen Kontrastmitteln bei weitem nicht vorzuziehen

RESUMÉ

Un nombre limité de myélographies ont été faites avec un nouveau moyen de contraste résorbable appelé SH-617 L Ce nouveau produit présente certains avantages mais il est loin d etre préférable aux autres moyens de contraste

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Fig. 1



2a



2b



2c

Fig. 1 (left) Lumbar myelogram. Defect on anterior surface of dura at level of L2-L3.
Fig. 2 a) and b) Total obstruction to contrast medium at level of T4-T5. (A neurinoma was found at operation.) c) Photograph taken during operation. The contrast medium is closely spread on the spinal cord at level of lesion.

fluid presented pleocytosis and an increased protein content. The irritative phenomena disappeared after a few days. This aseptical meningitis and related signs were especially strong in the normal myelographies, the irritative symptoms were milder when a total obstruction was present, possibly because of less extensive spreading of the substance.

The resorption of the contrast medium was slow. After 4 to 5 weeks it was much less noticeable, and only after 9 to 10 weeks was it no longer identifiable.

All the symptoms of the spinal compression showed a tendency to exacerbation. In one case, during the surgical exposure, we could observe the contrast medium closely spread like a thin film on the surface of the spinal cord (Fig. 2c).

We are unable definitely to evaluate the properties of SH 617 L, but in our view this contrast medium is in no way superior to the pantopaque and kindred substances.

SUMMARY

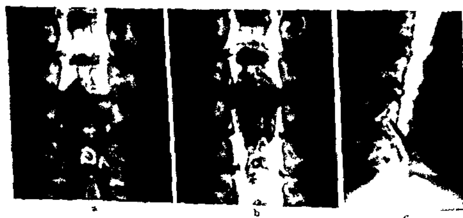
A limited number of myelographies have been carried out with a new resorbable contrast medium called SH 617 L. The new medium offers some advantages but it is far from being preferable to other contrast media.



a b

Fig 1 a) Lumbar route myelography Complete block at D2 without other elements of diagnostic value b) After urea the contrast medium flows beyond the obstacle and outlines the cord which is enlarged up to the level of the fifth cervical vertebra due to an intramedullary glioma

of 60 drops per minute With this technique we have not observed side effects except for mild headache in a few cases Half an hour after the termination of the urea perfusion the patients were re examined and new films taken after repeated tilting of the table in order to observe whether changes had occurred in the images of the block



a b c

Fig 2 Suboccipital route myelography Complete block probably due to an extramedullary lesion at the level of space C5-C6 b) and c) After urea the classical picture of C5-C6 intervertebral disc herniation appears.

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UREA IN POSITIVE CONTRAST MYELOGRAPHY

by

A. CALABRO and F. SMALTINO

In recent years the use of hypertonic urea solutions has been introduced in neuroradiology as a means of lessening cerebral edema and intracranial hypertension. This renders encephalographic examinations less dangerous, better tolerated and of increased pictorial quality. TURNBULL in 1962 said "Personal observation during a cervical cordotomy demonstrated that with urea the cord does shrink and the spinal theca becomes slack", and in 1963 JOYNER & FREEMAN demonstrated that the administration of hypertonic urea in the dog exerts an anti-edema effect on the spinal cord. This fact suggested to us the possibility of applying this effect in positive myelography, in the hope that a reduction of swelling might change a complete block into a partial one. If this were to be obtained, an improved definition of contour and size of the lesion could ensue and thus allow clarification of its anatomical relationships with the cord and its envelopes.

Methods. We have selected cases of complete myelographic block of the spinal space, where the image could not be modified either by extension, flexion or by axial rotation movements of the spinal column. Urea, in a 30 % glucose solution, was then injected intravenously in doses of 0.8 g/kg at a rate



Fig 1 a) Lumbar route myelography Complete block at D? without other elements of diagnostic value b) After urea the contrast medium flows beyond the obstacle and outlines the cord which is enlarged up to the level of the fifth cervical vertebra due to an intramedullary glioma

of 60 drops per minute With this technique we have not observed side effects except for mild headache in a few cases Half an hour after the termination of the urea perfusion the patients were re examined and new films taken after *repeated tilting of the table* in order to observe whether changes had occurred in the images of the block



Fig 2 a S boc ip tal route myelogr phy Complete block probably due to an extramedullary lesion at the level of space C5 C6 b) and c) After urea *the class cal* picture of C5-C6 intervertebral disc herniation appears


a b

Fig 3 a) Suboccipital route myelography Complete block at cervical level On the left side the opaque column stops at the level of the C6 C7 intervertebral space while on the right it does not go beyond the C5 C6 intervertebral space b) After urea the contrast medium passes over the obstacle and shows that the cord is swollen from the level of C6 to the inferior surface of DI

A total of 9 cases were studied during a period of 6 months, ending in March 1964 In 6 cases the block was caused by vertebral tumours, either primary or metastatic In these cases the administration of urea did not cause any modification in the myelographic block In the other 3 cases the administration of urea caused significant changes as briefly described below

Case reports

Case 1 In this case the presence of an intramedullary glioma was verified at a subsequent surgical operation By performing myelography by the lumbar route the flow of the opaque column appeared to be arrested completely at the level of the second thoracic vertebral body (Fig 1a) After infusion of urea the contrast medium flowed beyond the obstacle and showed the classical picture of an intramedullary lesion (Fig 1b)

Case 2 The contrast medium injected by the suboccipital route appeared immovably blocked at the level of the intervertebral space between C5 and C6 (Fig 2a) The images of this block of flow seemed to be those of an extramedullary space occupying lesion The picture persisted after the patient had been standing for a long time and despite repeated movements of flexion extension and rotation of the neck After urea the contrast fluid bypassed the obstacle and outlined the typical image of herniation of the C5 C6 intervertebral disc (Fig 2b)

Case 3 In this case the contrast medium injected by the suboccipital route was arrested asymmetrically at the cervical level (Fig 3a) Changes of position and movements did not modify this picture After urea the contrast medium flowed beyond the obstacle and showed that the cord below was enlarged The considerable enlargement of the cord was interpreted as being due to an intramedullary growth and this opinion proved to be correct when an intramedullary glioma (Fig 3b) was found at a surgical intervention

Conclusions

Although the number of cases studied by us is small as yet the use of hyper tonic urea solutions as an adjunct to myelographic procedures seems justi fied in some cases where the usual technique reveals the existence of a com plete block which is difficult to interpret diagnostically

SUMMARY

When a complete block is present at a positive contrast myelography it is sometimes difficult to locate an expansive lesion with respect to its relationships with the spinal cord or its coverings In some cases urea has been found to change a block from a complete into an incomplete one making it possible to use the modifications thus obtained for establishing a more precise diagnosis

ZUSAMMENFASSUNG

Bei Anwesenheit eines totalen Blocks ist es mit positiver Kontrastmyelographie manchmal schwerig eine expansive Veranderung mit Hinsicht auf ihre Beziehung zum Ruckenmark und seinen Hauten zu lokalisieren In einigen Fallen fand man dass Urea einen kompletten in einen inkompletten Block verwandeln kann Durch diese Modifikation wird es moglich die Dia nose zu verbessern

RESUMÉ

Quand il y a un blocage complet à la myelographie par moyen de contraste positif il est parfois difficile de localiser une tumeur par rapport a la moelle ou a ses enveloppes Dans certains cas on a constaté que l urée transforme un blocage complet en blocage incomplet permettant d utiliser des modifications pour établir un diagnostic plus precis

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OBSERVATIONS ON THE CIRCULATION OF THE CEREBROSPINAL FLUID

by

GIOVANNI DI CHIRO

I believe that most of us have been taught that the cerebrospinal fluid (CSF) slowly circulates (Fig 1), passing from the ventricular system, through the foramen of Magendie and the lateral clefts of Luschka, to the subarachnoid spaces at the base of the brain, and from there ascending towards the convexity of the brain where the greater part of its absorption occurs A lesser portion of the fluid descends along the posterior aspect of the spinal cord and then, in front of the cord, returns towards the mainstream The principal site of production of this fluid is the choroid plexus, the portals through which most of the fluid passses from the subarachnoidal spaces into the blood are the granulations of Pacchioni Even a superficial perusal of the literature will however, show that our actual knowledge on the production and absorption of the CSF and in particular on its circulation, is still in a state of considerable controversy and doubt This is due mainly to the fact that the CSF pathways and the fluid contained within them represent a system particularly difficult to study (BOWSHER 1960) To obtain reliable information on this system one has, in fact, to avoid opening it, so as not to change the hydrodynamic conditions under

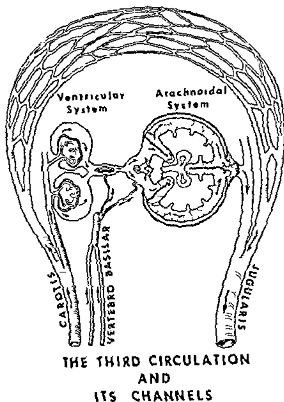


Fig 1 Routes followed by cerebrospinal fluid (Modified from Cushing)

which it normally subsists The subarachnoidal cavities are in addition peculiarly susceptible to the irritation caused by the presence of foreign bodies This markedly limits the possibility of obtaining valuable data by using extraneous tracers Finally the results of animal experimentation on the CSF system should cautiously be extrapolated to the human The advent of radio active isotopes in biology has allowed the study of the CSF system closer to its natural status and to accumulate a great deal of new information A certain number of previously broadly accepted concepts have been reappraised and new value has been given to concepts of early workers which had been shelved for many years

Limiting ourselves to the kinetics of the CSF and the factors regulating this movement it is obvious that a net transfer (flow) of fluid out of the ventricles into the subarachnoidal space must take place Obstructions of ventricular

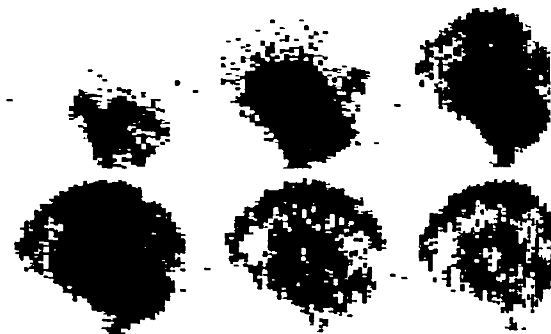


Fig. 2. Lateral serographic radio iodinated serum albumin cisternograms at 1, 3, 6, 12, 20 and 24 hours.

outflow, in fact, invariably result in hydrocephalus. Dyes injected into the lateral ventricles make their appearance in the cisterna magna within a few minutes (DANDY & BLACKFAN 1914, RISER 1929) and may be detected in the lumbar fluid after 10 minutes (SOLOMON, THOMPSON & PFEIFFER 1922). Pulsations of the fluid synchronous with respiration and cardiac systole has been stressed (O'CONNELL 1943) as an important factor for the maintenance of the CFS circulation and coughing, sneezing and straining considerably affect its motion (RISER 1929). SELL (1928) regarded vascular contractions as the major factor in the circulation of the fluid. This latter view has received support from the clinical observations of DOTT & GILLINGHAM (1958) on the formation of pouches along the course of the major cerebral arteries in cases of localized obstructions of the subarachnoid space. Most of us have observed pulsatile movements in the CSF pathways at fluoroscopy during Pantopaque myelography and in cineradiography of myelography and encephalography. The pulsations of the choroid plexuses and their volume changes at each heart beat are considered responsible by BERING (1955) for this to and fro motion of the CSF. With the filling of the choroid plexuses the ventricular content increases and fluid is actively pumped out of the ventricles. The emptying of the choroid plexuses results in a diminution of volume of the ventricular content and the fluid changes direction. Thus the pumping action of the choroid plexus would cause

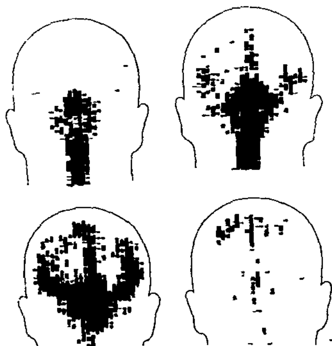


Fig 3 Sagittal seriographic radio-iodinated serum albumin cisternograms at 1 3 6 and 24 hours

an ebb and flow pattern of motion out of the ventricles and a slow progression of the CSF through the subarachnoidal spaces towards the surface and the convexity of the cerebral hemispheres Despite all these observations and theories no direct evidence has been offered that flow in a given direction actually exists in the CSF system In fact the present trend is to consider unlikely that any complicated circulation takes place in the subarachnoid space and that production and absorption of the CSF and its various constituents occur everywhere though not at the same rate in the fluid pathways If this is true because the fluid gets in and out of the system at every point no mainstream flow may exist in the CSF cavities The observations of various investigators on the ascending of drugs injected into the spinal subarachnoid space would tend to confirm this view WESTON (1921) injected phenol sulfonephthalein in patients SACHS WILKINS & SAMS (1930) trypan blue in dogs KOSTER et coll (1938) procaine in patients EICHLER LINDER & SCHMEISER (1951) radiosodium in dogs and FUNKQUIST (1961) methiodal in dogs With all these different substances the movement upwards into the spinal subarach

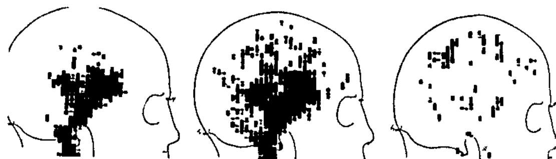


Fig 4 Activity spreads towards convexity mainly through anterior cisternal pathways

Fig 5 Penetration of tracer into ventricles from cisterns (upper left) Direct intraventricular injection (lower left) Encephalogram (upper right)

noid space was proven to be a very slow process SACHS and co workers reached the conclusion that movements in the spinal subarachnoid space are only due to simple diffusion and denied the existence of any direct fluid circulation in the spinal subarachnoid space HASSIN (1933) suggested that no caudal or cephalad flow of the spinal fluid exists but that this fluid moves only in a transverse direction

In 1962 we (RIESELBACH et coll) used scintillation detection to study the subarachnoid distribution of the drugs injected intrathecally In 8 patients (6

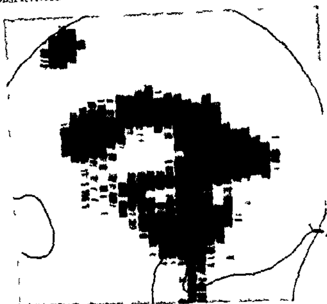


Fig 6 T cer out into ba al cisterns soon after ntravent cular ject on

with meningeal leukemia and 2 with medulloblastoma) ^{198}Au was injected intrathecally and taking advantage of the 10 % gamma emis ion of this isotope external scintillation canning was *performed* to determine the intracranial distribution of the radionuclide *In these* early experiments we were impressed by the constantly similar *distribution* pattern of the endocranial radioactivity We also noted that the barl otage *of fluid at the* injection and the positioning of the patient (even *Trendelenburg*) had no effect on the upward spreading of the radioactivity One factor *which proved* to be important and able to influence the rate of ascent of *the isotope* was the amount of fluid injected The larger the volume of solvent the *faster the* activity moved upwards towards the basal cisterns This data paralleled similar findings in monkeys using ^{131}I rose bengal and methiodal (RIESELBACH et coll 1962) We were able to obtain in one patient an autoradiography of a brain slice which showed a strikingly analogous activity distribution with the scans which had been done in vivo Microscopical examination of brain tissue revealed gold particles within microphages throughout the subarachnoid *space* We then passed on to use in neurological patients another tracer *namely radio* iodinated serum albumin (DI CHIRO 1964 1965 DI CHIRO & REAMES 1964 DI CHIRO REAMES & MATTHEWS 1964) which we have been injecting intrathecally *(isotope*





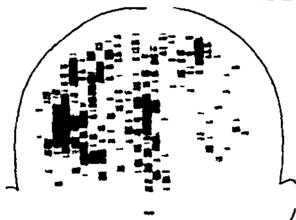


Fig 7 No air was visible at encephalography but at scintillography a pool of tracer was seen on right convexity At surgery a huge arachnoidal cyst was found at the site (see specimen)

cisternography) and intraventricularly (isotope ventriculography) The diagnostic value of the isotope cisternography and isotope ventriculography is now established The present report, however, is not mainly concerned with these diagnostic aspects, but with the possible applications to the physiology of the movement of the CSF Keeping this in mind we have used, in some patients, ^{131}I tagged autologous CSF Here the only foreign substance injected in the system is the tagging isotope The distribution pattern and the rate of flow of the tagged autologous CSF is analogous to the one observed with the radio iodinated serum albumin (Fig 2) At one hour the basal cisterns are well filled with activity, at three the activity has reached the Sylvian fissures at 12 it is over the convexity Generally at 24 hours high activity is present along the superior longitudinal sinus (Fig 3) The ascending of the fluid takes place mostly through the anterior subarachnoidal pathways (Fig 4) — cisterns in front of the brain stem, suprasellar subfrontal, prefrontal spaces — and the Sylvian fissures These are the highways of the CSF circulation In the posterior subarachnoid spaces (supracerebellar, occipital, posterior parietal) very little activity is seen At 24 to 48 hours, the injected tagged albumin is predomi

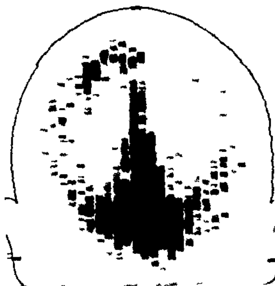


Fig 8 Partial block of CSF pathways at left tentorial notch Activity reaches convexity mainly through right routes

nantly often exclusively recognized in the parasagittal area, along the superior longitudinal sinus Though recently the so called Key and Retzius Weed (WEED 1914) hypothesis (i e that the largest resorption of CSF occurs through the arachnoid granulations) has been challenged by many investigators and in particular by HOWARTH & COOPER (1955) and KISS & SATTLER (1956), there is no doubt from our studies that a significant part of the CSF streams toward the region where these granulations abound Occasionally the activity penetrates into the ventricular system after intrathecal injection in such an amount as to be recognized pictorially in the scans through the familiar morphology of the ventricles (Fig 5) When the tracer is injected within the ventricles the passage into the cisterna magna takes place in a few minutes (Fig 6) Afterwards the spreading from the cisterna magna to the hemispheric convexity is analogous to the one observed in cisternography As expected individual variations play an important role We have constantly observed for instance that in children the spreading of activity is faster than in adults We would like to point out that most of our patients were epileptics Many of them had neuroradiological studies within normal limits

Quantitative determinations by head scanning of the amount of the intrathecally injected material which has reached the endocranium and of the amount which has remained in the lumbar area are at best gross Our judge





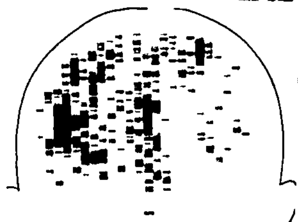


Fig 7 No air was visible at encephalography but at scintillography a pool of tracer was seen on right convexity At surgery a huge arachnoidal cyst was found at the site (see specimen)

cisternography) and intraventricularly (isotope ventriculography) The diagnostic value of the isotope cisternography and isotope ventriculography is now established The present report, however, is not mainly concerned with these diagnostic aspects, but with the possible applications to the physiology of the movement of the CSF Keeping this in mind we have used, in some patients, ^{131}I tagged autologous CSF Here the only foreign substance injected in the system is the tagging isotope The distribution pattern and the rate of flow of the tagged autologous CSF is analogous to the one observed with the radio iodinated serum albumin (Fig 2) At one hour the basal cisterns are well filled with activity, at three the activity has reached the Sylvian fissures, at 12 it is over the convexity Generally at 24 hours high activity is present along the superior longitudinal sinus (Fig 3) The ascending of the fluid takes place mostly through the anterior subarachnoidal pathways (Fig 4) — cisterns in front of the brain stem, suprasellar, subfrontal, prefrontal spaces — and the Sylvian fissures These are the highways of the CSF circulation In the posterior subarachnoid spaces (supracerebellar, occipital posterior parietal) very little activity is seen At 24 to 48 hours the injected tagged albumin is predomi

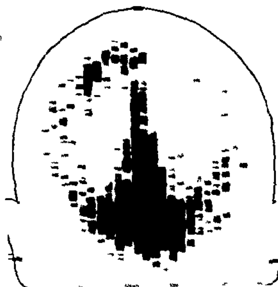


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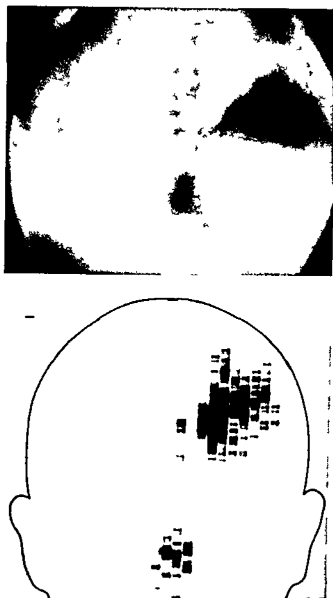


Fig 9 Spontaneous ventriculostomy with porencephalic cyst communicating both with lateral ventricle and subarachnoidal spaces Upper view Axial transverse encephalogram Lower view Isotope cisternogram

ment is that 1/5 to 1/3 (20 to 35 microcuries) of the hundred microcuries intro duced by lumbar puncture eventually reach the endocranium The lumbo sacral 'cul de sac' — as judged by external scintillation scanning—remains 'hot' for at least 48 hours

When using radio iodinated serum albumin, as we do in most instances, the albumin concentration has varied in our ventriculo and cisternograms from a

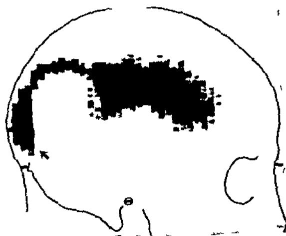


Fig 10 Blocked (arrow) ventriculo c sternal shunt.

minimum of 10 mg per ml (before adding the diluting Elliot s B solution) to a maximum of about 50 No appreciable distribution differences have been noted within this range of albumin concentration We generally work with preparations containing a specific activity of 500 microcuries per ml The total amount of fluid injected is 5 to 10 ml i e 1/15 to 1/30 of the commonly estimated 130 to 150 ml amount of CSF in adults As detected previously with gold labeled albumin also demonstrated that an increase in the volume of injected fluid increases the rate of upward movement of the tracer

This report is not as noted above concerned with the diagnostic applications of isotope ventriculography and cisternography However some pathologic cisterno and ventriculograms may be pertinent to emphasize some of our physiological observations Thus the injected radioactive material reaches every spot bathed by the CSF itself This is not always the case of the injected air in encephalography (Fig 7) Whenever and wherever a block to the free movement of the CSF exists the radioactive material follows other open routes to reach the hemispheric convexities (Fig 8) In fact in such instances the radio activity spreading through the open pathways is in higher concentration—vicarious function — than in cases in which no block exists The amount of radioactivity immediately proximal to a block is larger than normally seen — prestenotic dilatation of the subarachnoid pathways — this observation being in agreement with what Dott & Gillingham (1958) observed at surgery The labeled fluid passes through spontaneous (Fig 9) and surgical shunts (Fig 10)

The motion of the injected tagged albumin is undoubtedly more than a mere mixing effect or simple diffusion at least from the cisterna magna up

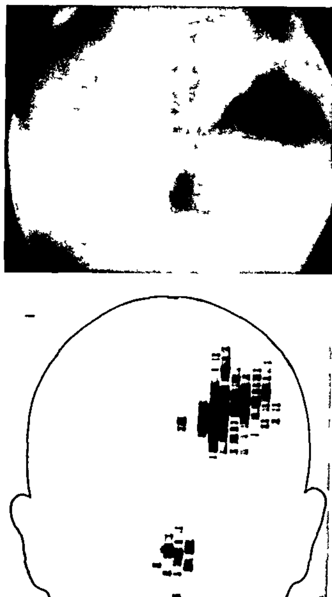


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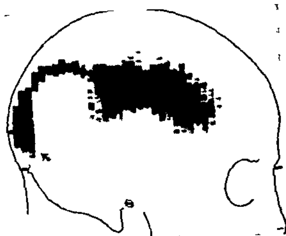


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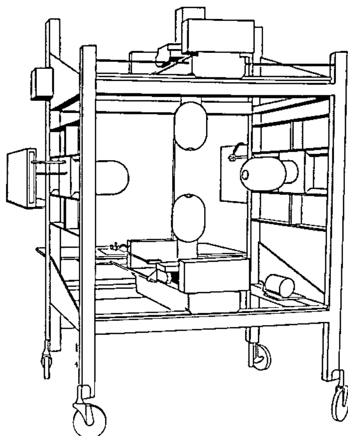


Fig 11 Four probe scanner

We are confronted, in my opinion, with a 'transport' or 'sweeping' phenomenon, possibly with an ebb and flow component but definitely with a net forward progression This may be a product of vascular pulsations, choroid plexuses pulsations, or may be caused by the vis a tergo of the newly formed fluid We wish to stress at this point that the movement of the tagged fluid through the cerebrospinal pathways is not affected by the movements or the positioning of the patient The same distribution pattern has been noted in patients kept supine and with the head lower than the feet and in other patients who, after the lumbar puncture, have freely moved and walked around the room

In three patients we have attempted to carry out an isotope cisternography using 500 microcuries of Technetium 99m (pertechnate —$^{99m}TcO_4$) The radioactivity never ascended towards the endocranium but spread freely from the lumbar region into the blood stream Already one hour after the intrathecal injection of the pertechnate one could demonstrate by head scanning the high activity in the salivary glands which one finds after the intravenous in

jection of the same isotope This was also the case in a patient in whom we injected 500 *microcuries* of Technetium 99m intraventricularly This confirms the observations of other investigators (HOWARTH & COOPER 1949 SWEET et coll 1954) of how critical is the molecular size when studying the CSF with tracers Tracers with small molecular size leave the CSF at the closest point and do not follow in any significant amount the CSF in its flow Therefore the observations made by others on the circulation of the CSF with radiosodium (EICHLER LINDEP & SCHMEISSER 1951) and the method suggested by CROW KEOGH & NORTHFIELD (1956) for the localization of CSF fistulae also with radiosodium, have little value

Isotope ventriculography and cisternography will offer additional information on the problem of the normal and abnormal CSF circulation when already available technical refinements are applied to these procedures With four probes (Fig 11) the scanning time will be markedly reduced and we will be able to study the movement of the tagged fluid simultaneously in the three dimensions With the gamma cameras and with the future cine registration and television monitoring fast recordings of the activity spreading will be possible With the technique of image separation or radioactive tomography (KUHL 1964) we will be able to evaluate how often a cisterno ventricular backflow of fluid occurs and how significant this is With tomography we will also probably be able to establish whether it is true that the spinal fluid moves in two streams in the spinal canal — descending behind the cord and ascending in front of it New ideas in the field of tracers for isotope ventriculography and cisternography are also worth pursuing, though it is our present opinion that serum albumin and in particular the autologous CSF tagged with iodine have many advantages Tagging the albumin with an isotope better suited for scanning work than ¹³¹I may be a lead worth following

Conclusions

1 With the techniques of isotope ventriculography and cisternography we may pictorially appraise the movement of the CSF in living humans

2 Our observations especially when using tagged autologous CSF, are made under almost ideal conditions i e a closed with no foreign substance physiological system

3 The CSF begins to leave the ventricular system very rapidly — within minutes

4 At least a part of the lumbo sacral CSF ascends to the basal cisterns This upward movement takes place in about 1 hour possibly faster in children

5 The fluid arriving in the basal cisterns from the ventricular system or the

spinal canal ascends toward the convexity of the brain following a constant pattern, through the anterior and Sylvian subarachnoid pathways in 4 to 8 hours

6 At 24 to 48 hours after the intraventricular or intrathecal injection, the tagged albumin 'crowds' in the parasagittal area, while little or no activity is evident in the rest of the CSF pathways

7 When a normal path is blocked the fluid moves along other open channels which, as vicariously functioning, let a larger amount of activity pass through than normally

8 The particle size of the tracers to be used to study the CSF flow is of critical importance Small molecules move freely out of the CSF cavities at the closest point and therefore do not follow the mainstream Other factors than particle size, such as electrical charge and lipoid solubility, possibly play an important role in this respect

9 It is probably true that the CSF is formed everywhere and resorbed everywhere in the CSF cavities It is also true, however, that possibly due to the vascular and choroid plexuses pulsations, plus the 'vis a tergo' of the newly produced fluid, at least a portion of this fluid moves in a current like fashion

SUMMARY

With the techniques of isotope cisternography and isotope ventriculography we have been able to ascertain that at least part of the cerebrospinal fluid moves in a flow within the fluid pathways in living humans This flow has been mapped by serial scans These observations give a better understanding of the normal and abnormal dynamics of the cerebrospinal fluid circulation

ZUSAMMENFASSUNG

Mit der Technik der Isotopen Cisternographie und Ventrikulographie konnten wir beweisen dass wenigstens ein Teil der Cerebrospinalflussigkeit sich in den Liquorraumen des lebenden Menschen flussartig bewegt Dieser Fluss wurde mit Serienscans ermittelt Diese Beobachtungen tragen zu einem besseren Verstandnis der normalen und abnormalen Dynamik der Liquorzirkulation bei

RÉSUMÉ

L auteur a pu par les techniques de cisternographie isotopique et de ventriculographie isotopique montrer qu une partie au moins du liquide céphalo-rachidien se déplace en un courant dans les voies liquidiennes chez l homme vivant Ce courant a été étudié par des scintigraphies en série Ces observations permettent de mieux comprendre la dynamique normale et pathologique de la circulation du liquide céphalo-rachidien

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RADIOLOGICAL ASPECTS OF SPINAL CYSTICERCOSIS

by

JAIME DORFSMAN

Cysticercosis of the central nervous system is well known in places such as Latin America India Russia some Mediterranean areas and other countries This type of cysticercosis may be either cer bral (DORFSMAN 1963) spinal or a combination of both Cerebral forms are the most frequent and best known The diagnosis is relatively simple when using encephalography and/or ventriculography in combination with the cerebrospinal fluid laboratory tests (DORFSMAN 1963) Spinal cysticercosis is the rarest form of this disease It is difficult to determine the real incidence of this form mainly because postmortem studies of the vertebral column are often ignored However, we have an approximate idea based on our clinical series the ratio being one hundred cerebral to one spinal On the other hand the ratio in our series of cerebral cysticercosis to the remainder of cerebral lesions which produce intracranial hypertension is 1 to 3 These approximate figures give us a good idea of the high frequency of cerebral cysticercosis and the rarity of spinal cysticercosis The reason for this difference is not known though some hypotheses have been advanced to explain this discrepancy The literature concerning spinal cysticercosis is very scanty (CABIESES et coll 1959) and we have no knowledge of any work which specifically describes the radiological changes in this disease



Fig 1 Multiple lumbar intradural extramedullary filling defects caused by vesicles of cysticercus One of them (arrow) was the only one among all cases which was seen to move in different positions (L 5 and L 4)



Fig 2 Single intradural extramedullary vesicle of cysticercus (arrow) associated with irregularities and fragmentation of the contrast medium in the lower cervical region

The present paper is based on the study of seven such cases, all of them subarachnoid, we have not seen any intramedullary cases, although this type has been described elsewhere (CABIESES et coll 1959) The localization was as follows one cervical, two in the cervico thoracic region, one thoracic (Th 10) and three in the lumbar region The clinical picture in all cases was a more or less advanced cord or radicular compression, and in none save one was it possible to make the etiological diagnosis using only the clinical findings The only case which was diagnosed clinically as spinal cysticercosis had cerebral cysticercosis as well Conventional films of the vertebral column showed no abnormalities related to the disease Myelography was performed in every case Five demonstrated intradural extramedullary filling defects variable in size and more or less spherical in shape In four cases these defects were multiple (Fig 1), being associated with adjacent irregularities and fragmentation of the column of contrast medium (Fig 2) The fifth case had a single defect which in turn produced a complete obstruction at C 2 (Fig 3) Four of these cases were diagnosed radiologically as probable, intradural extramedullary tumors, one of them suggesting the possibility of vascular malformation The other case was the only one diagnosed clinically and radiologically as spinal



Fig 3 Complete obstruction at C 2 (cisternal puncture) due to an intradural extramedullary vesicl



Fig 4 Arachnoiditis with small vesicles of cysticercosis Fragmentation and irregularities of the contrast medium with complete obstruction at Th 12



Fig 5 Expansive process at Th 1 diagnosed as possible intramedullary tumor (Courtesy of P BELTRAN)

cysticercosis The remaining two cases showed only marked irregularities deformities and fragmentation of the column of contrast medium with complete obstruction in one at Th 9 and in the other at Th 12 (Fig 4) These two cases were diagnosed as non specific arachnoiditis In all cases spinal fluid was taken during myelography the laboratory tests reported in each of them an inflammatory process of the type usually seen in cysticercosis In four cases the cysticercosis reaction was positive In the remaining three cases this reaction was not performed All cases were verified surgically demonstrating in all of them vesicles with multiple cysts localized in the subarachnoid space and associated with a severe adjacent arachnoiditis In the two cases where no myelographic filling defects were seen and only an arachnoiditis was demonstrated some of the vesicles were *bound* to the arachnoidal reaction and others were located distal to the site of obstruction This explains why the vesicles were not shown during the myelography

Although the myelographic diagnosis of these lesions is non specific from the experience acquired in these seven cases we can suggest that in places

where cysticercosis is a common disease, the presence in the myelogram of single or multiple, intradural extramedullary defects associated with an adjacent arachnoiditis, or arachnoiditis alone, would strongly indicate the possibility of spinal cysticercosis, which can be easily corroborated by the cerebrospinal fluid studies, specifically the cysticercosis reaction. With these two studies (myelography and cerebrospinal fluid tests) it will be possible to make the correct topographic and etiological pre-operative diagnosis in practically all of the cases. When making the radiological diagnosis of this disease, other multiple intradural extramedullary lesions such as neurofibromas, meningiomas and metastasis should also be borne in mind.

Another case was seen after this study had been completed, myelography suggested an intramedullary tumor (Fig. 5), but at operation a single intradural, extramedullary vesicle of cysticercus was encountered, well attached to the dorsal aspect of the cord, and was easily separated by blunt dissection.

SUMMARY

The myelographic changes of spinal cysticercosis are described on the basis of 8 observed cases. The appearances were not specific. In almost all cases the pre-operative diagnosis could be made with the aid of the spinal fluid laboratory tests.

ZUSAMMENFASSUNG

Es werden die myelographischen Veränderungen bei spinaler Cysticerkosis an Hand von 8 beobachteten Fällen beschrieben. Die Befunde waren nicht spezifisch. In fast allen Fällen konnte die Diagnose mit Hilfe der Laboruntersuchungen gestellt werden.

RÉSUMÉ

Description d'après 8 cas des signes myélographiques de la cysticercose médullaire. Les images ne sont pas spécifiques. Dans presque tous les cas les examens de laboratoire du liquide céphalo-rachidien ont permis de faire le diagnostic pré-opératoire.

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SYPHONAGE TECHNIQUE FOR REMOVAL OF PANTOPAQUE

by

B S EPSTEIN and J A EPSTEIN

Pantopaque myelography is in many quarters a standard procedure in the investigation of diseases of the vertebral column the spinal cord and its coverings While there is some question as to whether or not Pantopaque can remain safely within the subarachnoid space it is generally held that its removal is advisable At present this is accomplished by aspiration through the lumbar puncture needle as described by KUBIK and HAMPTON in 1941 The movement imparted to fluid within the spinal canal by the Valsalva maneuver of straining or coughing (EPSTEIN 1944 REITMAN 1941) also is used to facilitate its removal (SCOTT & FURLOW 1944) Not infrequently the patient complains of considerable pain during this part of the examination so much so that the procedure has to be discontinued The apprehension in the minds of patients and physicians as to the rigors of myelography should not be underestimated

The present study is concerned with the position of the needle tip in the spinal canal its relationship to nerve roots the configuration of the spinal canal and the withdrawal of Pantopaque by means of the creation of a syphon (EPSTEIN 1964) Experience with this technique in 40 consecutive myelographic examinations has shown that Pantopaque can be syphoned off quite completely and with little or no pain

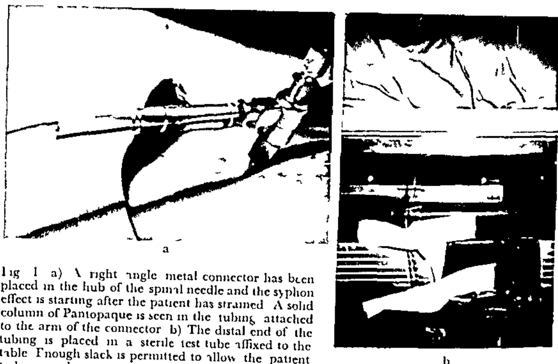


Fig 1 a) A right angle metal connector has been placed in the hub of the spinal needle and the syphon effect is starting after the patient has strained A solid column of Pantopaque is seen in the tubing attached to the arm of the connector b) The distal end of the tubing is placed in a sterile test tube affixed to the table Enough slack is permitted to allow the patient to be moved

The aspiration of Pantopaque from the lumbar subarachnoid space is facilitated when the tip of the spinal needle is at or close to the midline and somewhat above or below the level of an intervertebral disc A relationship exists between the configuration of the spinal canal and the ease of instillation and removal of Pantopaque (Epstein et coll 1964) Quite often the introduction of a lumbar puncture needle into a lumbar canal with an anteroposterior diameter of less than 1 2 cm is difficult, and removal of Pantopaque is more likely to be troublesome and painful On the other hand, a wide canal usually permits easy introduction and aspiration of the contrast material Intrusions of discal material or spondylotic spurs into canals of wider dimensions may be without clinical significance while similar lesions can be productive of severe disturbances in patients with narrow canals (Epstein et coll 1962, Verbiest 1954)

Whether the lumbar spinal canal is normal in width and configuration or narrowed, intrusion of a nerve root into the lumen of the needle tip will interrupt the flow of Pantopaque while it is being aspirated This occurs even with the needle tip placed in the midline but is more likely to take place when the canal is narrowed Even the gentlest aspiration may be quite painful, and the patient often complains of exquisitely localized radicular pain at that time If the needle tip is situated laterally the possibility of intraluminal



Fig 2 a) The tip of the lumbar puncture needle is situated far in the left lateral recess at the fourth interspace The canal is of normal dimensions b) The syphon tube is connected directly to the hub of the needle No flow is taking place A nerve root is seen close to the needle tip c) After rotation of the needle syphonage proceeded satisfactorily Only a few droplets of Pantopaque remain

intrusion of a nerve root is increased and painful unsuccessful attempts at aspiration follow Manipulating and twisting the needle often produces nothing more than added discomfort and may be accompanied by bleeding into the subarachnoid space Furthermore the needle tip must be placed as close as possible to the floor of the canal for the successful removal of Pantopaque Otherwise only clear cerebrospinal fluid or fluid mixed with Pantopaque is withdrawn

During the past six months we have employed a syphon method for the removal of Pantopaque A syphon effect is created when a sterile polythene tube is attached to the hub of the lumbar puncture needle by way of either a three way stopcock or a right angle metal connector This is preferred to direct attachment of the tube because it reduces the height of the apparatus Syphonage also is improved if the lumbar puncture needle used is as short as possible The distal tip of the drainage tube is placed in a sterile container about 30 cm below the level of the spinal canal A valve may be placed in the system to interrupt the flow at times The system should be air tight so that the syphon action is not interrupted by air bubbles Flow is started by having the patient strain or take a series of deep breaths Occasionally it is necessary to aspirate gently from the distal end of the system Usually the flow continues nicely once the head of the fluid column is below the level of the needle tip Manipulation of the position of the Pantopaque is greatly facilitated by the use of image intensification This permits the radiologist to minimize the quantity of fluid removed by keeping the Pantopaque column at the tip of the needle So long as the

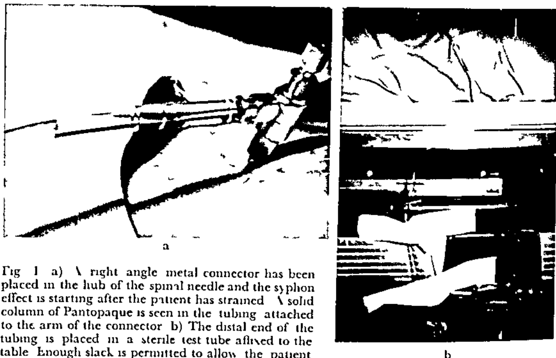


Fig 1 a) A right angle metal connector has been placed in the hub of the spinal needle and the syphon effect is starting after the patient has strained A solid column of Pantopaque is seen in the tubing attached to the arm of the connector b) The distal end of the tubing is placed in a sterile test tube affixed to the table Enough slack is permitted to allow the patient to be moved

The aspiration of Pantopaque from the lumbar subarachnoid space is facilitated when the tip of the spinal needle is at or close to the midline and somewhat above or below the level of an intervertebral disc A relationship exists between the configuration of the spinal canal and the ease of instilla tion and removal of Pantopaque (EPSTEIN et coll 1964) Quite often the introduction of a lumbar puncture needle into a lumbar canal with an anteroposterior diameter of less than 1 2 cm is difficult, and removal of Panto paque is more likely to be troublesome and painful On the other hand, a wide canal usually permits easy introduction and aspiration of the contrast material Intrusions of discal material or spondylotic spurs into canals of wider dimensions may be without clinical significance while similar lesions can be productive of severe disturbances in patients with narrow canals (EPSTEIN et coll 1962, VERBIEST 1954)

Whether the lumbar spinal canal is normal in width and configuration or narrowed, intrusion of a nerve root into the lumen of the needle tip will interrupt the flow of Pantopaque while it is being aspirated This occurs even with the needle tip placed in the midline, but is more likely to take place when the canal is narrowed Even the gentlest aspiration may be quite pain ful, and the patient often complains of exquisitely localized radicular pain at that time If the needle tip is situated laterally the possibility of intraluminal

space because the patients immediately mentioned that pain could be felt on the affected side radiating to the lower extremity, the buttock or the perineum If the flow of cerebrospinal fluid was free the Pantopaque was injected under image intensification control Eleven of these patients had narrowed canals with the sagittal diameters less than 1 3 cm in diameter at the level of the spinal tap Four patients had normal spinal canals The removal of Pantopaque by syphonage was successful in 11 patients without delay In 3 the needle tip became occluded by a nerve filament The needle was rotated to disengage the obstruction whereupon syphonage continued In one patient the needle tip rested in the subdural space and no return was obtained The arachnoid became depressed as the needle was advanced Withdrawal and reinsertion one interspace lower was followed by rapid syphonage

The quantity of fluid removed by syphonage is quite variable If one is careful to permit the syphon to function only when Pantopaque is being removed the procedure may be performed with removal of about 20 or 25 ml of clear cerebrospinal fluid Often this is not within the control of the radiologist because a needle with a relatively long bevel will permit passage of a considerable quantity of cerebrospinal fluid towards the end of the procedure For this reason we prefer a relatively short bevelled needle The control of the position of the Pantopaque column often is rather unpredictable Only an examiner who has observed the vagaries of a Pantopaque column towards the end of the syphonage can understand how vexing the removal of the last drop can be However the fact that Pantopaque can be removed quickly relatively completely and often without pain makes the procedure worth while

SUMMARY

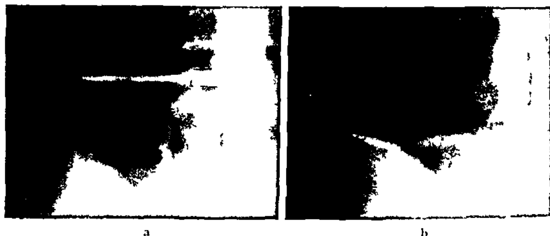
A syphonage technique is described which has been used successfully for the removal of Pantopaque from narrow as well as from wide canals with the needle tip placed centrally or laterally

ZUSAMMENFASSUNG

Eine Aspirations-Technik die bei der Entfernung von Pantopaque aus engen wie auch aus weiten Kanalen erfolgreich war wird beschrieben Die Lage der Nadelspitze war zentral oder lateral

RESUME

Description d une technique de siphonage utilisée avec succes pour retirer le Pantopaque de canaux étroits ou larges l extrémité de l aiguille étant placée au centre ou latéralement



a b

Fig 3 a) The syphonage is beginning and a solid column of Pantopaque is seen in the tubing b) Towards the end of the procedure droplets of Pantopaque are interspersed with cerebrospinal fluid Practically complete evacuation was obtained

bevel of the spinal needle is completely immersed in Pantopaque its passage is uniform This can be watched either through the image intensifier or by inspecting the transparent polythene tube Towards the end of the procedure the bevel becomes only partly immersed, so that an emulsion of cerebrospinal fluid and Pantopaque passes through the tube When the last droplets are marshalled to the needle tip it is not uncommon to observe a bead like arrangement of drops of Pantopaque and cerebrospinal fluid

This procedure has been successful in 38 out of 40 consecutive patients in whom from 10 to 35 ml of Pantopaque had been injected into the subarachnoid space Adequate removal was attained in that less than approximately 0 25 ml of Pantopaque or a few tiny globules remained in the canal in 14 patients In four about 0 5 ml persisted because the globules could not be marshalled to the tip of the needle In two patients the needle tip was occluded by a nerve root and replacement of the needle was required This was done by partly withdrawing the needle and reinserting it into the same interspace after checking the position and direction of the needle with the image intensifier

In 25 patients the needle tip was at or close to the midline and in 24 of these the Pantopaque was syphoned off quickly and painlessly Of these, 18 had spinal canals which were normal in configuration In 7 the sagittal diameter of the canal at the level of insertion of the needle was between 1 0 and 1 3 cm In one patient a nerve filament occluded the orifice of the needle and some manipulation was required to free the tip In 15 patients the needle tip was off center, often close to the lateral margins of the spinal canal We could usually predict this as soon as the needle tip entered the subarachnoid

FROM THE DEPARTMENT OF NEUROLOGIC SURGERY, C
OHIO U.S.A.

EMBRYOLOGIC ORIGIN OF SPINAL MALFORMATIO

by

W. JAMES GARDNER

In acquired disease states the terms early and mild as ... severe are almost synonymous whereas the opposite ... disorders. In the investigation of a disease process it is ... begin with the study of mild cases and progress to the ... was followed unintentionally in the study of certain ... the central nervous system The accumulated ... syringomyelia as representing the mild expression of ... which in its severe form is responsible for myelocele ... for meningocele and diastematomyelia

The cavity of syringomyelia consists fundamentally ... canal of the cord (hydromyelia) This di... frequently is enclosed in a dilated portion ... this bony canal also constitutes an essential ... diastematomyelia Klippel Feil syndrome ... bifida (hemivertebrae) and of posterior ... above L 5 In each of these conditions ... cord within the dilated tube of bone ... neural tissue within a dilated tube of ... relationship

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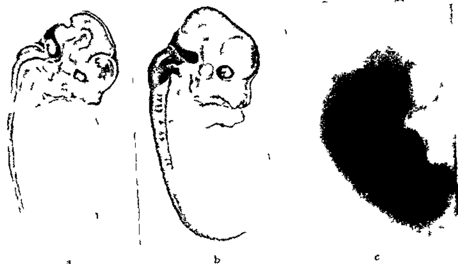
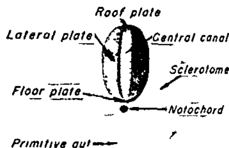


Fig 2 Pig embryos 18 mm (a) and 26 mm (b) corresponding in development to the sixth and eighth week in the human reduced to same overall length in order to better depict the increased distention of the neural tube in the older embryo This degree of *hydrocephalus and hydromyelia* is physiologic in embryonal life It is obstructive until the sixth week when fluid is just beginning to push through attenuating areas in the rhombic roof It is communicating at the eighth week by which time the entire subarachnoid space has been dissected open Neural tubes outlined with precipitated crystals of Prussian blue Severe overdistention of the neural tube at the sixth week (a) will result in posterior rupture (myeloschisis) of the less mature caudal somites to constitute the embryonic forerunner of myelocele This escape of fluid from the neural tube interferes with the dissection of the subarachnoid space Overdistention occurring after the development of the subarachnoid space (b) may cause the meninges to bulge posteriorly without rupturing because the skin being more mature is tough Compensation may then occur and the infant will be born with a meningocele covered with intact skin If separation of the lateral plates of the neural tube also has occurred diastematomyelia will be present *beneath the meningocele A sixth week human embryo (c) photographed in* its amniotic sac by transillumination The fluid filled portions are lighter and correspond to the dark areas in (a)
(a and b Courtesy Carnegie Institution of Washington)

Hydromyelic theory Two hundred years ago MORGAGNI (1769) was unencumbered with the knowledge that the sac of a myelocele consists of an open neural tube and therefore must represent failure of closure of the embryonal neural groove *From his observations* he naively concluded that these watery tumors of the vertebrae result from the pressure of fluid descending from the hydrocephalic head through the tube of the spine and pressing the bones asunder More than a century later VON RECKLINGHAUSEN (1886) disputed this hydromyelic mechanism Because his microscope revealed an open portion of the neural tube *within the sac he* believed it to be the result of failure of closure Von Recklinghausen s belief since has been repeatedly confirmed albeit by investigators whose observations were based on this preconceived idea It is



Photomicrograph of
16-somite human embryo



Photomicrograph
shown diagrammatically



Dilatation of neural tube
Stage 1



Separation of roof and floor plates
Stage 2



External rupture
Stage 3



External and internal rupture
Stage 4

Fig 1 Effect of overdistention of neural tube on surrounding germ layers Because the roof and floor plates as seen in the photomicrograph and the diagram are thin with little reinforcing tissue they will yield readily in response to overdistention of the lumen At *stage 1* if overdistention becomes compensated the roof and floor plates though stretched remain intact and syringomyelic *symptoms* develop in adulthood At *stage 2* the continuity of the roof and floor plates is interrupted If compensation then occurs the lateral plates may close separately to form two hemicords and diastematomyelic symptoms develop in adolescence Above the diastematomyelia is hydromyelia At *stage 3* if the neural tube ruptures through the overlying ectoderm (posterior myeloschisis) compensation *cannot occur* and myelocele is obvious at birth the open everted spinal cord may be split (diastematomyelia) and cephalad to it the cord is hydromyelic If as shown in *stage 4* the floor *and* roof plates rupture (posterior and anterior myeloschisis) the fetus dies in utero with a gut fistula presenting in a myeloschisis

(Photomicrograph Courtesy E C Sensenig Carnegie Institution of Washington)



Fig 4 Syringomyelia stage 1 the patient's symptoms developed at the age of 11 years A distended tube of neural tissue (a) was found within the dilated tube of bone (b)

ure of closure of the neural plate (myeloschisis) can be reproduced by slitting open the closed neural tube It is further supported by the work of HOLTZER (1952) who demonstrated that the diameter of the developing spinal canal of the embryo is determined by the diameter of the neural tube that it encloses He found that migrating precartilage cells respond in a discriminatory and stereotyped fashion to the presence of any neural tissue by maintaining a characteristic distance from the neural tissue The precartilage cells are deployed in such a fashion that a lumen will eventually be formed in the cartilage whose size is a function of the enclosed nerve bundle HOLTZER did not point out that if transverse stretching of the precartilaginous sclerotomes occurs because of overdistention of the neural tube these paired cell masses may fail to unite not only posteriorly but anteriorly as well resulting in combined anterior and posterior spina bifida (complete hemivertebrae Fig 1) Furthermore such transverse stretching of the sclerotomes will result in their longitudinal shortening and approximation so that these cell masses

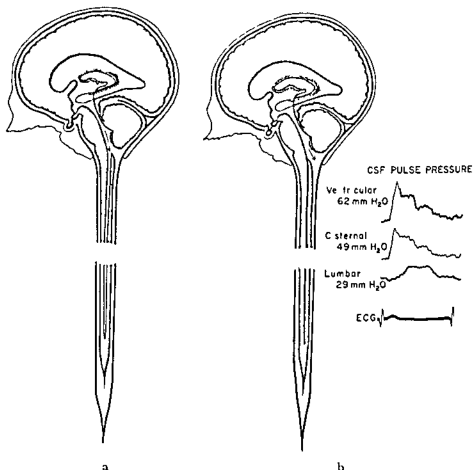


Fig 3 Cerebrospinal fluid spaces represented diagrammatically a) Until the foramens perforate the central canal constitutes a long diverticulum of the fourth ventricle Its lumen receives the pulse waves of the ventricular fluid (arrow) generated by the pulsations of the choroid plexus b) After the foramens perforate the ventricular fluid pulse waves are shunted into the subarachnoid space (arrow) and the central canal is compressed to vestigial remnant Recordings are from Bering (1955)

now fitting that Morgagni s disruption hypothesis receive similar consideration, particularly since von Recklinghausen s theory does not explain how a tube that has never closed becomes overdistended On the other hand, Morgagni's theory of rupture from overdistention will explain every feature of the distorted anatomy not only of myelocele, but also of related malformations, such as meningocele, diastematomyelia syringomyelia and Klippel Feil syndrome (GARDNER 1964)

Embryology This 200 year old hydromyelic theory gains support from FOWLER's (1953) demonstration that the microscopic appearance attributed to fail



Fig 4 Syringomyelia stage I the patient's symptoms developed at the age of 11 years A distended tube of neural tissue (a) was found within the dilated tube of bone (b)

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Fig 5 Diastematomyelia stage 2 a) From this patient 5 years old when examined a meningocele had been removed at birth Symptoms of diastematomyelia developed at the age of 12 years Operation then disclosed a divided spinal cord at the level of the bony spur as well as hydromyelia of stage 1 Dilatation shortening fusion scoliosis and partial hemivertebrae constituting Klippel Feil syndrome of the lumbar spine are seen b) Same patient as in (a) The dilatation of the cervical canal indicates that hydromyelia involved this level as well The a p diameter at C1 was 30 mm at C2 24 mm c) and d) Similarity to the Klippel Feil syndrome is better shown in these films of the lumbar spine of another adolescent with diastematomyelia This patient in addition to the vertebral changes had the fused ribs frequently encountered in the short neck syndrome (c and d Courtesy GEORGE E MARR and ALFRED UHLEIN W B Saunders Company)

may coalesce longitudinally to form fused vertebrae Thus, the stretching that interferes with normal fusion in the transverse axis of the spine may be accompanied by shortening with abnormal fusion (tethering) in its long axis Overdistention will explain other skeletal distortions as well, such as fused ribs and scoliosis to constitute the fullblown picture of Klippel Feil syndrome

Occurring prior to the development of the subarachnoid space overdistention of the neural tube also will cause a coalescence of neuroectoderm with mesoderm, cutaneous ectoderm or endoderm and result in fusion (tethering) of the neural tube to these surrounding cell layers Subsequent splitting off of these coalesced cell masses by the dissecting subarachnoid space will explain the glial cell rests in the meninges which COOPER and KERNOHAN (1951) found in the adult with syringomyelia as well as in the infant with myelocele It also will account for other types of hamartomas either in the spinal cord or in surrounding structures An example is the occurrence of gut epithelium in the bony spur of diastematomyelia This line of reasoning appeals to the mechanically oriented mind of the surgeon It affords an explanation of such vague entities as dysraphia and 'dysplasia It makes it unnecessary to

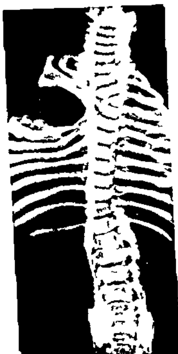


Fig 6 Film of the skeleton of an infant with myelocele In addition to the midline bony spur there is fusion of L 1 and 2 widening and shortening of the spinal canal with scoliosis hemivertebrae and fused ribs all features of Klippel Feil syndrome (Courtesy A H CAMERON Oliver and Boyd Ltd)

invoke such hypothetic considerations as retardation of the blastophore (CAMERON 1957) accessory neuroenteric canal (BREMER 1952) or any of the earlier theories that SAUNDERS (1943) has summarized in his review of the subject

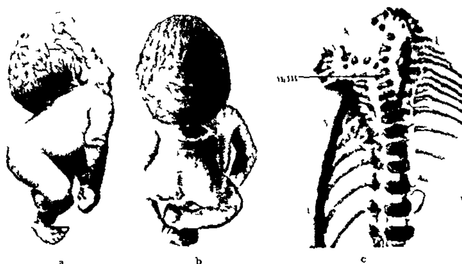
A fact usually overlooked by the clinician is that the embyonal neural tube is a single cavity which constitutes the anlage of the ventricles and the central canal of the cord Distention of this tube, that is hydrocephalus and hydromyelia (hydrocephalomyelia) is a normal state in embryonic life (Fig 2) This physiologic distention becomes compensated as the ventricular fluid filters through the attenuating rhombic roof to dissect open the subarachnoid space As pointed out by WEED (1917) if for any reason the roof of the fourth ventricle does not become adequately permeable during the critical sixth to eighth week period a sufficient quantity of fluid will not filter through it to properly dissect open the developing subarachnoid space In this event even though the roof subsequently perforates to form the foramens, communicating hydrocephalus may prevail Thus in 1917 WEED explained not only the mechanism of congenital hydrocephalus both obstructive and communicating and why both forms frequently co exist but his illustrations also show



Fig. 5. Diastematomyelia, stage 2. a) From this patient, 5 years old when examined, a meningocele had been removed at birth. Symptoms of diastematomyelia developed at the age of 12 years. Operation then disclosed a divided spinal cord at the level of the bony spur as well as hydromyelia of stage 1. Dilatation, shortening, fusion, scoliosis and partial hemivertebrae constituting Klippel-Feil syndrome of the lumbar spine are seen. b) Same patient as in (a). The dilatation of the cervical canal indicates that hydromyelia involved this level as well. The a. p. diameter at C1 was 30 mm, at C2 24 mm. c) and d) Similarity to the Klippel-Feil syndrome is better shown in these films of the lumbar spine of another adolescent with diastematomyelia. This patient, in addition to the vertebral changes, had the fused ribs frequently encountered in the short neck syndrome. (c and d Courtesy GEORGE L. MARR and ALFRED UIHLEIN, W. B. Saunders Company.)

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a b c

Fig. 8. a) and b) Stillborn fetus with severe Klippel-Feil syndrome and myelocele. c) After removal of head in Klippel-Feil syndrome, the marked disruption of the vertebral halves suggests an almost explosive force within its lumen. (Courtesy A. FELLER and H. STERNBERG, Springer Verlag.)



a b

Fig. 9. a) Skeleton of Klippel-Feil syndrome in an adult. b) Film of this skeleton shows the tremendous dilatation of the cervical canal. The neurologic picture of Klippel-Feil syndrome is syringomyelia. (Courtesy A. FELLER and H. STERNBERG, Springer Verlag.)

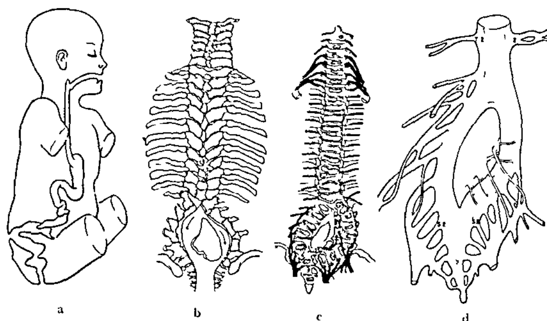


Fig. 7. If the roof plate ruptures into the amniotic sac (stage 3) and the floor plate simultaneously ruptures into the primitive gut (stage 4), the result is a gut fistula (a) presenting posteriorly between the *two halves of the* split spinal canal (b and c) and the cord (d). The diastematomyelic cord (stage 2) was hydromyelic (stage 1).

clearly that hydrocephalus developing in embryonal or fetal life must be accompanied by hydromyelia. Therefore, if hydrocephalus with hydromyelia is present in postnatal life, and particularly if the outlets of the fourth ventricle are found unperforated, as is true in many cases of syringomyelia, diastematomyelia, meningocele, and myelocele, this represents not a new condition, but the pathologic persistence of a state that is normal in the embryo. That Weed's views are not widely accepted is a striking example of the time lag so often separating laboratory demonstration and clinical acceptance.

The central canal of the cord takes off from the floor of the fourth ventricle at the level of the obex. In the normal adult with patent fourth ventricle foramens, the central canal is narrow if not entirely closed. Contrariwise, in individuals in whom the foramens have failed to perforate, the central canal is dilated (GARDNER 1964). This reciprocal relationship suggests that normally the central canal narrows because the foramens open, and conversely, if the foramens do not open, the central canal dilates. This is logical, for if the foramens fail to open, even though filtration is adequate to maintain normal intraventricular pressure, the central canal will continue to receive the thrust of the ventricular fluid pulse wave generated by the beating of the choroid plexus. On the other hand, when the foramens open this waterhammer

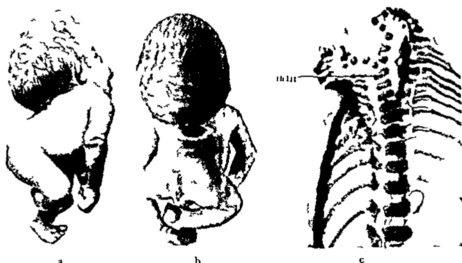


Fig. 8a) and b) Stillborn fetus with severe Klippel-Feil syndrome and myelocele. c) After removal of head in Klippel-Feil *syndrome* the marked disruption of the vertebral halves suggests an almost explosive force within its lumen. (Courtesy A. FELLER and H. STERNBERG, Springer Verlag.)



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effect is shunted past the central canal into the subarachnoid space. Here its force exerted on the outer surface of the spinal cord will tend to compress and close off its lumen (Fig. 3).

The normally dilated central canal of the embryonic cord shrinks as the physiologic hydrocephalus becomes compensated. Because of this same compensatory process, a pathologic overdistention of the central canal may be reduced to normal. Despite such reduction the stretched sclerotomes having taken a set still may proceed to form a dilated spinal canal. Therefore, a spinal cord of normal diameter within a dilated canal, as in the cases reported by WALKER (1944), is no indication that the cord was *not* overdistended in embryonal life. By the same token, a normal degree of distention of the neural tube during the precartilaginous stage followed by overdistention at a later stage may result in a hydromyelic spinal cord within a bony canal of normal diameter. Thus is explained the findings of WELLS, SPILLANE, and BLIGH (1959) that when syringomyelic symptoms develop after age 30 the cervical canal usually is of normal diameter, whereas, in the more severe cases in which symptoms develop before age 30 it usually is dilated.

The skeletal features of the Klippel-Feil syndrome consist of varying degrees and combinations of dilatation, shortening, bifid states, fusion of the vertebral column, scoliosis and deformities of the rib cage. Until now Klippel-Feil and short neck syndrome have been considered synonymous. However any or all of these skeletal deformities may be present at the level involved by myelocele, meningocele, diastematomyelia, tethered cord or syrinx (Figs. 4—9, GARDNER 1964). The one feature of Klippel-Feil syndrome present in all of these congenital malformations is dilatation of the vertebral canal, which fact certainly supports the premise that the neural tube was overdistended in the sclerotome stage.

SUMMARY

Syringomyelia, diastematomyelia, meningocele and myelocele with their accompanying skeletal changes are the result of varying degrees of overdistention of the neural tube in embryonic life. The defect responsible for this overdistention is inadequate permeability of the rhombic roof.

ZUSAMMENFASSUNG

Syringomyelie, Diastematomyelie, Meningocele und Myelocele mit ihren begleitenden Skelettveränderungen sind das Ergebnis von verschiedenen Graden von Überstreckung des Neuralrohres während des embryonalen Lebens. Das Ergebnis dieser Überstreckung ist insuffiziente Permeabilität des Daches des Rautenhirns.

RÉSUMÉ

La syringomyélie la diastématomyélie la méningocèle et la myélocèle ainsi que les malformations squelettiques qui les accompagnent sont *le résultat de divers degrés de* surdistension du tube neural au cours de la vie embryonnaire Le defaut cause de cette surdistension *est une perméabilité* insuffisante du toit du rhomber céphale

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Syringomyelia, diastematomyelia, meningocele and myelocele with their accompanying skeletal changes are the result of varying degrees of overdistention of the neural tube in embryonic life. The defect responsible for this overdistention is inadequate permeability of the rhombic roof.

ZUSAMMENFASSUNG

Syringomyelie, Diastematamyelie, Meningocele und Myelocele mit ihren begleitenden Skelettveränderungen sind das Ergebnis von verschiedenen Graden von Überstreckung des Neuralrohres während des embryonalen Lebens. Das Ergebnis dieser Überstreckung ist insuffiziente Permeabilität des Daches des Rautenhirns.



Fig 1 Thoracic myelogram Vertical beam decubitus view using Pantopaque 15 Herniated calcified thoracic disc at Th 6–7



Fig 2 Lateral cervical myelogram with Pantopaque 30 Evaluation of the ventral cord margin difficult with standard technique (top) With the high kilovoltage technique the ventral cord margin is visible (below)

the visibility of the cord in the lateral view with both Pantopaque 22 % and 30 % (Fig 2) This was more apparent with Pantopaque 30 % However one could obtain the same visibility with average techniques using Pantopaque 22 % with preservation of bony detail This tends to be lost with higher kilo voltage techniques

Pantopaque 22 % is slightly more difficult to follow fluoroscopically over the foramen magnum However with experience and the use of image intensification it presents no problem Because Pantopaque 22 % has a lower specific gravity it flows more slowly over the dorsal spinal kyphosis This is a distinct advantage in myelography of the thoracic spine It is however less desirable in the cervical region

The optimal amount of contrast material for the *lumbar region* will cover three intervertebral disc spaces in the prone position and also cover the L4-5 and L5 S1 disc spaces in the erect position An amount of 12 ml of contrast material is sufficient in the vast majority of patients

In lumbar myelography it is desirable to demonstrate the roots and root

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ADVANTAGES OF A LESS DENSE PANTOPAQUE CONTRAST MATERIAL FOR MYELOGRAPHY

by

E RALPH HEINZ, RAY A BRINKER and JUAN M TAVERAS

Pantopaque, 30 % iodinated ethyl phenyl undecanoate, has been used widely since RAMSEY et coll made their initial report in 1944 Recently there has been a trend toward using greater volumes of contrast material to better fill the subarachnoid space With larger volumes of Pantopaque 30 % the subtle differences in density are obscured

Material and Methods A new form of Pantopaque, consisting of 15 % iodinated oil, was provided by Lafayette Pharmaceutical Inc A total of 132 consecutive myelographies were performed with patients randomly allocated

The important myelographic aspects in the cervical region are the demonstration of the spinal cord, the roots and the root sleeves Pantopaque 15 % was tried initially in this study and was acceptable in most cases However, in cases of severe spondylosis the anatomic details were often difficult to observe, due to insufficient density

It was our impression that high kilovoltage technique definitely increased



Fig 5 Lumbar myelograms with Pantopaque 15 The displaced nerve roots are well shown

possible to simplify the choice of contrast material by using Pantopaque 22 % If a given concentration of Pantopaque is too dilute in appearance it can be made more concentrated by adding Pantopaque 30 % Conversely, a dense concentration of Pantopaque may be diluted by the addition of Pantopaque 15 %

The conus medullaris can be shown by using large amounts of Pantopaque 15 % (up to 20 ml) This structure is usually obscured when Pantopaque 30 % is used (Fig 7)

The number of *thoracic myelographies* performed is too small for statistical analysis Since large volumes are necessary to perform a proper examination of the thoracic region 20 ml was arbitrarily used in this study and it proved to be suitable in every case Frontal fluoroscopic spot films were greatly facilitated because the larger volume tended to move more as a column even in the difficult Th6—Th7 area of dorsal spinal kyphosis Lateral films with the patient in the prone position were routinely included This was accomplished by pooling the large Pantopaque column at the C3—Th5 region by frontal fluoroscopy The cassette for the lateral views should be positioned and the films taken 5 seconds after raising the head of the table 10 degrees Thus the Pantopaque is flowing over the Th5—Th12 area as the film is exposed (Fig



Fig. 3. Lateral cervical myelogram with Pantopaque 22 % using 0 ml. The ventral and dorsal margins of cervical and upper thoracic cord are well shown.



Fig. 4. Lateral and oblique films with Pantopaque 22 % using 20 ml. Excellent demonstration of the basilar artery despite the lower concentration of Pantopaque.

sleeves as well as a double contour on the ventral side of the column when there is unilateral disc protrusion (Figs. 5 and 6). Pantopaque 15 % is not as satisfactory as the water soluble material to demonstrate the cauda equina roots but it does represent a slight improvement over Pantopaque 30 %.

Several lumbar myelograms done utilizing Pantopaque 22 % indicate that it is intermediate between Pantopaque 15 % and 30 %. Since Pantopaque 22 % seems optimal for use in the cervical and dorsal regions it may be



Fig 8 Lumbar myelogram with 15 ml of Pantopaque 15 Frontal view The conus medullaris and cauda equina are visible This requires a greater volume of Pantopaque than the usual lumbar myelogram

The appearance of the cord in the lateral projection (cord lateral) was evaluated the appearance was then evaluated in the anteroposterior diameter (cord anteroposterior) and then the nerve roots and nerve sleeves were evaluated Excellent visibility was rated at 100 % good at 75 %, fair at 50 % and poor at 25 % The average was then listed for the varying concentrations of Pantopaque and quantities of material used (Table 1)

In the cervical region Pantopaque 22 % using either 12 ml or 20 ml was considerably better in all respects than using 30 % Pantopaque The use of 20 ml of Pantopaque 22 % resulted in considerably better analysis of lesions in the cervical region

In the lumbar region the films were analyzed again using nerve root visibility root sleeve visibility and double density as criteria Specifically, we

Table 1

Evaluation of cervical myelograms The numbers are averages 100 being excellent visibility of details Cord lateral refers to appearance of the spinal cord in the lateral prone projection cord a p to the anteroposterior view Concentrations of Pantopaque indicated on left side of table

Pantopaque		Cord lateral	Cord a p	Nerve roots	Nerve sleeves
22	12 ml	69	84	53	56
22	20 ml	83	75	75	83
30	12 ml	56	71	56	64
30	20 ml	54	58	58	54




Fig. 6. Lumbar myelogram with Pantopaque 15%. Lateral view (left) shows double contour at L4 to 5 and the frontal (right) unilateral extradural impression. Herniated nucleus pulposus.

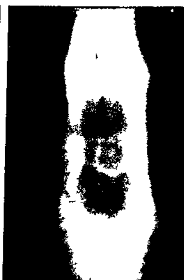


Fig. 7. Thoracic myelogram. Lateral prone view. The large column of contrast (20 ml) is positioned at the lordotic cervical curve.

8). This technique is considerably aided by the lighter, and correspondingly slower flowing, Pantopaque 22 %. Finally, lateral decubitus films, with vertical and horizontal beam direction, were exposed (see Fig. 1).

Discussion

One of the most difficult problems in Pantopaque myelography is evaluation of the cervical cord dimension in the lateral view. The sagittal cord diameter is critically important when the transverse diameter of the cord is widened. Using larger volumes of Pantopaque 22 % one can define the ventral and dorsal margins of the cord in every case (Figs. 3 and 4). Thus, the differential diagnosis of intramedullary cord disease or ventral extramedullary lesions such as spondylosis, cervical disc, or a ventrally placed meningioma, can be made.

When larger quantities of Pantopaque 30 % are used, the ventral margin of the cord is often not seen. High kilovoltage technique facilitated the demonstration of the cord margins but the bony margins so important for correlation are less distinct (Fig. 2).

Evaluation of cases. All of the myelograms were reviewed by the authors without knowledge of which concentration of Pantopaque had been used.



Fig 8 Lumbar myelogram with 25 ml of Pantopaque 15 Frontal view The conus medullaris and cauda equina are visible This requires a greater volume of Pantopaque than the usual lumbar myelogram

The appearance of the cord in the lateral projection (cord lateral) was evaluated the appearance was then evaluated in the anteroposterior diameter (cord anteroposterior) and then the nerve roots and nerve sleeves were evaluated Excellent visibility was rated at 100 % good at 75 % fair at 50 %, and poor at 25 % The average was then listed for the varying concentrations of Pantopaque and quantities of material used (Table 1)

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2	12 ml	69	84	53	56
22	20 ml	83	75	75	83
30	12 ml	56	71	56	64
30	0 ml	54	58	58	54

Table 2

Evaluation of lumbar myelograms. The same principles of evaluation were applied as in table 1

Pantopaque	Nerve root visibility	Root sleeve visibility	Double density
15 % 9 ml	50	32	36 %
15 % 12 ml	62	64	25 %
30 % 9 ml	46	54	20 %
30 % 15 ml	53	64	20

were interested in learning if Pantopaque 15 % resulted in improved root sleeve filling. *However, visibility of the root sleeves was the same with Pantopaque 30 % and Pantopaque 15 % (Table 2).* Extradural impressions on the Pantopaque column were more frequently seen with Pantopaque 15 %. Smaller extradural impressions could be detected more readily utilizing Pantopaque 15 % because of the greater spectrum of contrast recorded.

Thoracic myelography has been facilitated by large volumes of Pantopaque. Frontal fluoroscopic spot films are done in the usual manner. There is better filling as a result of a large column. Lateral films taken in the horizontal direction in the midthoracic region are impossible with small volumes of contrast material. With larger volumes and the slower flow of Pantopaque 22 % excellent films may be obtained defining the ventral subarachnoid space in the sagittal plane. With the method described the time required for an optimal thoracic myelogram can be greatly reduced. Removal of the large volumes described presents little, if any, additional difficulty over existing methods. The importance of a well centered spinal needle with the bevel directed either cephalad or caudad cannot be overemphasized.

Acknowledgement

Drs Heinz and Brinker undertook this study as Special Fellows NB 973 02 and NB 974 02, National Institute of Neurological Diseases and Blindness, NIH.

SUMMARY

Larger volumes of Pantopaque add considerably to the ease of performance and diagnostic accuracy of myelography. These larger volumes require less concentrated contrast material than Pantopaque 30 %. Optimal volume in the cervical region is Pantopaque 22 % in 15 to 20 ml quantities. In the lumbar region 12 ml of Pantopaque 15 % is ideal while 20 ml of Pantopaque 22 % *is used in the thoracic region.*

ZUSAMMENFASSUNG

Die Verwendung von grosseren Mengen Pantopaque erleichtern die Diagnosestellung bei der Myelographie Infolge der grosseren Kontrastmenge kann die Konzentration von Pantopaque unter 30 gehalten werden Fur die Cervicalregion ist die optimale Menge 15 bis 20 ml 22 Pantopaque In der Lumbalregion genugen 12 ml 15 Pantopaque wahrend in der Thorakalregion 20 ml 22 °₀ Pantopaque verwendet wird

RÉSUMÉ

L emploi d une quantite plus importante de Pantopaque facilite l exécution de la myélographie et augmente sa précision diagnostique Ces grandes quantités permettent d utiliser un moyen de contraste moins concentré que le Pantopaque a 30 ° Pour la région cervicale on utilisera 15 a 20 ml de Pantopaque a 22 ° pour la région lombaire 12 ml de Pantopaque a 15 et pour la region dorsale 20 ml de Pantopaque a 22

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PANTOPAQUE ARACHNOIDITIS

Experimental study of blood as a potentiating agent and corticosteroids as an ameliorating agent

by

W. J. HOWLAND and J. L. CURRY

This study was initiated to investigate the reasons for the occasional development of severe arachnoiditis following myelography with ethyl iodophenylundecylate (Pantopaque, Myodil). There are numerous reports in the literature of signs and symptoms of severe arachnoiditis with operative (2, 7, 8, 10, 12) or autopsy (1, 3, 5, 9) confirmation of severe meningeal inflammation. The idea occurred to us that subarachnoid bleeding during the course of needle positioning might produce an added irritant factor which would occur in only occasional patients and that this might explain the occasional development of severe arachnoiditis. Review of the literature available to us has not disclosed any previous investigation of this possibility. SARKISIAN in 1956 suggested that a bloody tap should be considered a contraindication to the injection of oil intrathecally, evidently basing this recommendation on the possibility of emulsification of oil. JAEGER's studies of the harmful effects of emulsified oils were cited.

Because of difficulties encountered in ascertaining whether or not subarachnoid bleeding had occurred in human clinical material, it was decided to

evaluate he effect of blood mixed with Pantopaque in the subarachnoid space of dogs Initial studies of this problem (4) prompted us to expand these investigations Following the publication by SEHGAL et coll (1962) of successful treatment of chronic symptomatic pantopaque arachnoiditis with subarachnoid injections of corticosteroids we decided to investigate the possibility of prevention of arachnoiditis in experimental animals

Material and Methods A total of 24 mongrel dogs in good clinical condition were used In all dogs, the contrast material was injected into the cisterna magna through a posterior midline puncture with a 20 gauge infant spinal needle using aseptic technique The injection was made with the animal in a 60 caudal tilt and the neck flexed The neck was extended immediately upon completion of the injection In this position almost all of the contrast material flowed slowly along the subarachnoid space to the lumbar region over a period of approximately one hour The injection was made slowly after preliminary withdrawal of 5 ml of spinal fluid Roentgenograms were obtained at intervals until the contrast medium reached the lumbar region The animal was maintained under light pentobarbital anesthesia during this period

Two dogs were injected with 3 ml of blood alone Four were injected with 3 ml of Pantopaque Six were injected with 3 ml of Pantopaque and 3 ml of blood Six more dogs were injected with 3 ml of Pantopaque and 20 mg of methylprednisolone acetate and six were injected with 3 ml of Pantopaque plus 3 ml of blood plus 20 mg of methylprednisolone acetate The blood was withdrawn from the animal s leg vein immediately prior to injection and mixed with the Pantopaque or the Pantopaque and corticosteroids in the syringe and injected before clotting had occurred

The dogs were sacrificed 6 to 8 weeks following injection with the exception of two animals which had to be sacrificed earlier Films were exposed at the time of sacrificing the animals These films were compared with the initial roentgenograms to estimate the amount of Pantopaque absorbed from the subarachnoid space in this interval

Complete central nervous system autopsies were performed Following fixation inflammatory response was graded grossly and microscopically by two examiners without knowledge of the material that the animal had received

Results

Injection of blood The two animals which received only blood showed no significant clinical symptoms There was minimal nuchal rigidity in both animals after the injection but this rapidly disappeared and these animals




Fig 1 Subarachnoid injection of Pantopaque alone Smooth symmetrical distribution of the oil column




Fig 2 Same dog as in fig 1 8 weeks later Most of the opaque oil has been absorbed

remained in good health until the time of sacrifice Autopsies showed no significant abnormality of the spinal cord and microscopic studies were also normal

Injection of Pantopaque Clinically these four animals showed very little difference from the animals which received only blood No obvious neurologic deficiencies developed during the period of observation and they were all in excellent health when sacrificed

Roentgenograms made at the time of injection showed a smooth symmetrical oil column (Fig 1) At autopsy, 6 to 8 weeks later, films showed the Pantopaque to be dispersed in small droplets and globules Comparison of the roentgenograms made at the time of injection and at the time of sacrifice showed that over one half of the Pantopaque had been absorbed (Fig 2)



Fig 3 a) Subarachnoid injection of Pantopaque mixed with blood The oil is fragmented into globules with uneven dispersion b) Same dog 8 weeks later A considerable volume of the oil remains and is most concentrated in the lower cervical region

Grossly the spinal cord and meninges showed multiple small areas of oily material with slight to moderate arachnoid thickening Much of the Pantopaque remained free within the subarachnoid space The microscopic appearance was one of mild chronic inflammatory reactive change about small encysted oil droplets

Injection of blood mixed with Pantopaque Clinically all of these animals had severe reactions The day following injection there was severe nuchal rigidity and apathy All dogs went through an initial period where food and water were refused All of these dogs were febrile for the first few days following injection Three of the six animals developed definite paralysis of the extremities and in one this progressed to complete paralysis of the hind limbs This paraplegic dog was sacrificed on the 18th post injection day The others gradually recovered their appetite and became afebrile Three of these six dogs ap-




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Table

Summary of Pantopaque arachnoiditis

	Blood alone	Pantopaque alone	Pantopaque and blood	Pantopaque and MPA	Pantopaque blood MPA
Number of animals	2	4	6	6	6
Average gross inflammation (0 — 4 +)	0	2	3 7 (1D)	1 3	1 9 (1D)
Average microscopic inflammation (0 — 4 +)	0	2 3	3 0	1 6	2 2
Average amount Pantopaque remaining	—	46	76	43	52

inflammation induration of the arachnoid This was most striking in the lower cervical region (Fig 4) Grossly some oily material was associated with the visible lesions and it was difficult to find any oil free in the subarachnoid space

Microscopically the inflammatory areas were seen to occur about cystic spaces No bacteria could be identified (Fig 5)

Injection of Pantopaque and methylprednisolone acetate Clinically none of these animals showed any significant reaction except for minimal transient nuchal rigidity and post anesthesia lethargy All animals remained in good health until the time of sacrifice without development of any neurological abnormality

Roentgenograms obtained at the time of injection showed the Pantopaque column to be less smooth and symmetrical when compared to Pantopaque alone There was more tendency for the oil to disperse into globules Roentgenograms made at the time of sacrifice showed a similar appearance Although less than half of the Pantopaque remained this was essentially the same as with animals receiving Pantopaque without corticosteroids (Table)

Grossly and microscopically there were many small areas of meningeal inflammation very similar to that seen with Pantopaque alone although generally somewhat less

Injection of Pantopaque blood and methylprednisolone acetate Clinically two of the six animals had a moderately severe reaction with temperature elevation apathy and refusal to eat Both of these developed some paralysis of the hind limbs and one died 19 days following injection The other four showed surprisingly little clinical abnormality

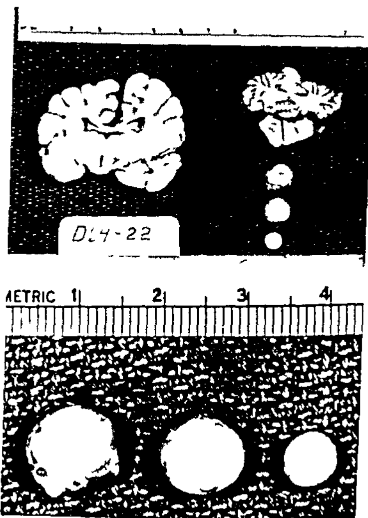


Fig 4 Postmortem specimens of dog sacrificed 8 weeks after subarachnoid instillation of I antopaque mixed with blood Inflammatory reaction surrounding oil droplets in the cervical cord region (lower left) at this level subarachnoid inflammatory reaction was usually most intense

peared to be in good clinical condition at the time of sacrifice 6 to 8 weeks following injection

In all of these animals, roentgenograms obtained at the time of injection showed the Pantopaque column to be broken into many large globules and poorly dispersed in the subarachnoid space (see Fig 3a) At the time of sacrifice, roentgenograms showed a similar appearance and considerably more Pantopaque remained in the subarachnoid space than in the dogs injected with Pantopaque alone (see Fig 3b)

Autopsy in all of these animals revealed moderately severe to very severe

Discussion

A potentiating action of blood in the production of Pantopaque arachnoiditis was remarkably consistent in this small series Each of the six animals in which blood mixed with Pantopaque was injected showed a moderately severe or very severe inflammatory reaction which was consistently more than that produced by Pantopaque alone This occurred in spite of the lack of significant inflammatory reaction produced by blood alone

The results of addition of corticosteroids are not as clear cut Certainly this did not give complete protection from the inflammatory response produced either by Pantopaque or Pantopaque mixed with blood Comparing the overall inflammatory response as judged by gross inspection and microscopic examination there was very little difference between the animals which received Pantopaque alone and those which received Pantopaque and methylprednisolone acetate However when the two groups of animals which received Pantopaque and blood are compared there does appear to be a significant difference All six of the animals which received Pantopaque and blood developed severe arachnoiditis whereas only two of the six which received Pantopaque and blood and methylprednisolone acetate developed severe arachnoiditis

A potentiating action of blood traumatically introduced into the subarachnoid space suggests a logical explanation for the severe arachnoiditis occasionally encountered following Pantopaque myelography Therefore, it may be inadvisable to introduce Pantopaque into the subarachnoid space if there is evidence of gross bleeding when the spinal puncture is performed It also seems equally important to be extremely careful to avoid subarachnoid bleeding during the removal of the Pantopaque

In an effort to prevent arachnoiditis the instillation of methylprednisolone acetate into the subarachnoid space at completion of Pantopaque myelography seems worthy of further investigation especially if subarachnoid bleeding occurs during removal of the oil

The reason for the potentiating action of blood in the production of Pantopaque arachnoiditis is not known Various possible decomposition products produced by the mixture of these two substances have been investigated There is no significant difference in free phenol levels in the spinal fluid To the present time we have not been able to ascertain any consistent difference in free iodine levels in the spinal fluid produced by the mixture of blood and Pantopaque Blood does not act as an emulsifying agent for Pantopaque in the presence of spinal fluid

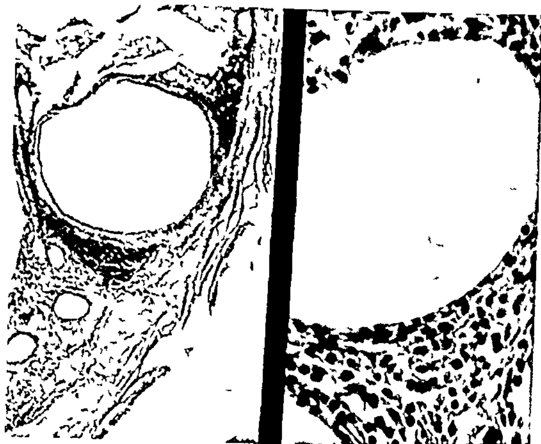


Fig 5 Low (left × 40) and high (right × [illegible]00) power photomicrographs (hematoxylin and eosin) of lower cervical cord segment from dog sacrificed 8 weeks after intrathecal injection of Pantopaque blood mixture The most intense inflammatory reaction is in close proximity to the oil droplets

Roentgenograms at the time of injection showed the oil to be dispersed in globules in much the same manner as when the corticosteroid was not added Roentgenograms made at the time of autopsy showed considerable residual Pantopaque but not as much as in the animals who received Pantopaque and blood without methylprednisolone acetate

The animal which died 19 days following the injection showed severe arachnoiditis in the cervical region and this appeared to be the cause of death There were other areas of arachnoiditis of less severe degree in more caudad portions of the arachnoid One other animal showed severe arachnoiditis in the cervical region with many localized areas of involvement However, the other four animals that received methylprednisolone acetate in addition to the Pantopaque and blood showed minimal inflammatory changes

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SUMMARY

Experimental studies of pantopaque arachnoiditis in 24 dogs were conducted Pantopaque alone caused mild arachnoiditis blood alone produced no significant reaction a mixture of blood and Pantopaque produced severe arachnoiditis When methylprednisolone acetate was added to the blood and Pantopaque mixture only two of six animals developed severe arachnoiditis The studies suggest that Pantopaque should not be injected intrathecally if gross bleeding is present The use of intrathecal corticosteroids should be considered if subarachnoid bleeding has occurred

ZUSAMMENFASSUNG

Es wurden experimentelle Studien von Pantopaque bedingter Arachnoiditis an 24 Hunden durchgeführt Pantopaque allein verursacht nur leichte Arachnoiditis Blut allein erzeugt keine nennenswerte Reaktion Eine Mischung von Blut und Pantopaque erzeugt eine schwere Arachnoiditis Wenn der Pantopaque Blutmischung Methylprednisolonacetat zugesetzt wurde entwickelte sich nur bei zwei von 6 Tieren eine ernsthafte Arachnoiditis Aus diesen Studien geht hervor dass Pantopaque nicht intrathekal injiziert werden sollte wenn eine massive Blutung vorhanden ist Injektion von intrathekalen Corticosteroiden sollte erwogen werden wenn eine subarachnoidale Blutung aufgetreten ist

RESUME

Les auteurs ont fait une étude expérimentale de l arachnoidite au pantopaque sur 24 chiens Le Pantopaque seul cause une arachnoidite légère le sang seul ne produit pas de réaction importante le mélange de sang et de Pantopaque donne lieu à une arachnoidite grave Après addition d acétate de méthylprednisolone au mélange de sang et de Pantopaque deux chiens seulement sur six ont présenté une arachnoidite grave D apres ces travaux il semble qu on ne devrait pas injecter de Pantopaque dans l espace intradural quand il y a une hémorrhagie importante On devrait envisager l administration de corticostéroides par voie intradurale dans les cas ou il s est produit une hémorragie sous arachnoidienne

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mobility of the thoracic spine and to the lesser frequency of disc herniations it has less clinical implications than in the cervical spine

Movements of the cervical spinal cord can be found in every individual providing there is enough space available in the spinal canal On the contrary, adequate movements of the thoracic spinal cord exist only in approximately 50 % of normal subjects This was found to be in correlation with the degree of permeability of the posterior arachnoidal space In 117 normal individuals this space was adequately filled with gas in 50 % of cases, in 25 % the filling was incomplete, and in 25 % it did not fill at all This seems to be due to individual differences in the density of the arachnoidal trabeculae An analysis of 169 subjects showed that in older individuals this space filled better and more frequently than in younger ones The differences are statistically significant and they seem to indicate that the trabecular tissue becomes thinner and finally disappears as it undergoes relatively early senile involution These pneumographic correlations have been confirmed by anatomic studies (JIROUT FISCHER & NADVORNÍK) Our studies showed a definite correlation between the degree of filling of the posterior thoracic arachnoidal space and the extent of mobility of the spinal cord In the great majority of cases — over 80 % — in which this space filled well, the mobility of the spinal cord was adequate whereas in cases in which this space was not permeable mobility was absent Thus our findings seem to indicate that a decrease or absence of the movements of the thoracic spinal cord in older individuals may be more often regarded as pathologic than in young subjects These facts must be borne in mind in the evaluation of abnormal conditions

Whenever an abnormal position of the spinal cord is found, it is advisable to examine such a condition more thoroughly The patient should be turned to a position which would enhance the shift of the spinal cord to the opposite wall of the spinal canal It should then be possible to differentiate a pathologic immobilization of the spinal cord, for instance by a neoplasm or arachnoidal adhesions from an artefact caused by the position of the patient before the procedure

The immobilization of the spinal cord in cases of meningomyelocele is mainly due to its extravertebral position and sometimes to arachnoidal adhesions In an 11 year-old boy the spinal cord entered into an anterior meningocele at the level of the upper thoracic spine At this level the cord was immobilized whereas the nearby segments had good mobility

In the Arnold Chiari malformation the upper cervical spinal cord may be immobilized on account of a very low protrusion of the cerebellar tonsils or by the arachnoidal adhesions frequently connected with this anomaly In other patients a backward shift of the cord in the supine position disclosing

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MOBILITY OF THE SPINAL CORD UNDER ABNORMAL CONDITIONS

by

JAN JIROUT

Through our previous pneumographic studies, the existence of the movements of the spinal cord in the anteroposterior direction resulting from changes of the position of the body was assessed. The extent of this mobility under normal conditions has been measured in large groups of individuals, and this has made it possible to evaluate the mobility under abnormal conditions.

It seems that a pathologic increase in mobility, if it exists at all, is rare. It is not certain that the considerable mobility of the thoracic spinal cord observed in some individuals can be regarded as abnormal. A relative increase in the mobility of an atrophic segment of an otherwise immobile thoracic spinal cord is also rare.

It appears, therefore, that it is practically only the decrease in mobility which is of clinical interest.

Developmental narrowing of the cervical spinal canal, as frequently seen in normal individuals, is an obvious cause of decreased mobility of the spinal cord. In a group of 280 patients a narrowing of the sagittal diameter of the cervical canal to less than 12 mm was found in 16 %; in these cases there was thus practically no possibility for the spinal cord to move. Considerable narrowing of the thoracic spinal canal is much less frequent. Owing to the lesser

the cord dorsally and prevent it from moving forward when the patient is in the prone position

Fixation of the spinal cord by metastatic medulloblastomas can be readily detected The upper cervical cord is deformed and loses its normal mobility if pressure from the intracranial space is exercised in the direction of the axis of the brain stem The resulting dorsal dislocation dorsal bulging and fixation of the cord in this pathologic position in supra and *infratentorial brain tumors* was described previously (JIROUT 1959)

In angiomas not only changes in the position of the spinal cord but also differences in the filling of the venous channels due to postural changes may be observed These variations make a correct diagnosis of the nature of these lesions possible Similarly in syringomyelia the level of maximal dilatation of the spinal cord may vary according to the position of the patient

On the whole the observation of displacements of the spinal cord due to postural changes of the patient constitutes in our opinion an extremely valuable help in the diagnosis of pathologic processes in the spinal canal

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Slides demonstrating the mobility of the cord were shown at the Symposium

SUMMARY

The previous pneumographic assessment of the existence and normal range of the movements of the spinal cord has made it possible to evaluate changes under abnormal conditions A pathologic increase in the mobility is rare a decrease in mobility is of major clinical interest The possible artefacts are discussed The diagnostic importance of evaluation of the mobility of the spinal cord in developmental disturbances in neoplasms in arachnoidal adhesions and in discopathies is also stressed

ZUSAMMENFASSUNG

Der fruher gelieferte pneumographische Nachweis des Vorhandenseins und der Grosse der Bewegungen des Ruckenmarkes hat es ermoglicht Veranderungen unter abnormalen Bedingungen zu studieren Eine pathologische Erhohung der Beweglichkeit ist selten die Abnahme de Beweglichkeit ist jedoch von grosserem klinischen Interesse Mogliche Artefacte werden besprochen Es wird die diagnostische Bedeutung des Studiums der Mobilitat des Ruckenmarks bei Entwicklungsstorungen Neoplasmen arachnoidalen Adhasionen und Discopathien hervorgehoben

RÉSUMÉ

Des travaux antérieurs ayant établi l existence et l étendue normale des mouvements de la moelle épinière permettent d en apprécier les modifications dans des conditions anormales L augmentation pathologique de la mobilité de la moelle est rare la diminution de sa mobilité presente un grand intéret clinique L auteur examine les artéfacts possibles Il souligne l importance diagnostique de l appréciation de la mobilité de la moelle épinière dans les troubles du développement les néoplasies les adhérences arachnoidiennes et dans les discopathies

a wide anterior arachnoidal space, practically settles the problem of the differential diagnosis of some types of this developmental malformation from neoplasms of the upper cervical region (J Jirout 1958)

Spondylotic spurs or disc protrusions are a frequent cause of immobility of the cervical spinal cord, especially if the spinal canal is narrow The decrease or absence of natural movements is a valuable sign of a close contact between the anterior aspect of the spinal cord and the pathologic structures A protrusion or herniation of a thoracic disc prevents the spinal cord from shifting ventrally when the patient is in the prone position A disc herniation of considerable size not only causes an immobilization of the cord but also changes its form and position The cord is stretched and bent over the protruding mass lesion like a violin string

Gas myelography makes it possible to differentiate these conditions from similar findings due to the retractional effect of the arachnoidal adhesions Immobilization of the spinal cord is an indirect sign of arachnoidal adhesions Nevertheless, in evaluation of these findings, we must bear in mind that clinically asymptomatic adhesions frequently occur They are either of congenital origin or residual arachnoidal adhesions after inflammatory processes of the meninges or of the neighbouring tissues, for instance in connection with lung tuberculosis

Examination of the mobility of the spinal cord is a valuable adjunct whenever a mass lesion is suspected The immobilized segments of the cord adjacent to the tumor may be readily distinguished from those whose normal mobility is still preserved These findings are most valuable in cases in which clinical symptoms are inconclusive In tumors, an absence of physiologic movements of the spinal cord can be expected whenever the mass lesion attains a sufficient size to prevent the cord from shifting We observed that at the level of an extramedullary tumor situated dorsally the mobility of the thoracic spinal cord is decreased, while in other parts it may be well preserved On the other hand, a ventrally situated tumor causes streching of the cord and impairment of the mobility of the whole spinal cord Similar findings may be seen in extradural tumors In intramedullary neoplasms, the mobility of the spinal cord depends entirely on the size of the mass lesion If it is small the mobility may be well preserved In tumors of the upper lumbar spine the question may arise, whether there is any connection with the spinal cord If the neoplasm is without any connection with the lower end of the spinal cord the mobility of these segments remains unimpaired On the other hand, an intramedullary lesion growing caudally necessarily causes immobilization of the caudal end of the cord The extramedullary tumors on the ventral aspect of the upper cervical spinal cord or in the foramen magnum displace

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Examination of the mobility of the spinal cord is a valuable adjunct whenever a mass lesion is suspected. The immobilized segments of the cord adjacent to the tumor may be readily distinguished from those whose normal mobility is still preserved. These findings are most valuable in cases in which clinical symptoms are inconclusive. In tumors, an absence of physiologic movements of the spinal cord can be expected whenever the mass lesion attains a sufficient size to prevent the cord from shifting. We observed that at the level of an extramedullary tumor situated dorsally the mobility of the thoracic spinal cord *is decreased, while in other parts it may be well preserved.* On the other hand, a ventrally situated tumor causes streching of the cord and impairment of the mobility of the whole spinal cord. Similar findings may be seen in extradural tumors. In intramedullary neoplasms, the mobility of the spinal cord depends entirely on the size of the mass lesion. If it is small the mobility may be well preserved. In tumors of the upper lumbar spine the question may arise, whether there is any connection with the spinal cord. If the neoplasm is without any connection with the lower end of the spinal cord the mobility of these segments remains unimpaired. On the other hand, an intramedullary lesion growing caudally necessarily causes immobilization of the caudal end of the cord. The extramedullary tumors on the ventral aspect of the upper cervical spinal cord or in the foramen magnum displace

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CONGENITAL TUMOURS OF THE SPINAL CORD

by

G LOMBARDI and A PASSERINI

Nineteen congenital tumours of the spinal cord corresponding to 4 8 % of the 347 spinal tumours operated on up to the end of 1963 have been recorded The distribution by type was 10 lipomas 5 dermoids 3 epidermoids and 1 teratoma

Lipomas accounted for 2 90 % of tumours of the spinal cord which is well above the 1 % reported by other workers (EHNI & LOVE 1945 EPSTEIN 1962) They were observed in 6 women and 4 men Larger series than the one now reported reveal the same non significant difference Six lipomas were intradural and 4 extradural a distinction important in several respects

Intradural lipomas It is thought that these are derived from lipoid cells in the pia mater or from fatty transformation of connective tissue Histologic examination reveals adult adipose tissue with no evidence of embryonal fat cells no trace of glial tissue is evident either which confirms the mesenchymal origin of the tumour The signs and symptoms to which these lipomas give rise are generally very slowly progressive at times interrupted by spontaneous remission The tumours are at least at first extramedullary but they develop such intimate connexions with the cord as to appear and behave

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tumours erosion of the pedicles and increase in the interpedicular distance, with or without arcuate indentation of the dorsal aspect of the vertebral bodies Only in the case of the teratoma and in one case of epidermoid were the changes very extensive

Calcification was observed in 2 cases The relative incidence in congenital tumours (10 %) is distinctly higher than in the total of 347 tumours of the spinal cord (1 6 %) There is frequent mention in the literature of the concomitant presence of other malformations of the cord or spine or both, but the authors observed these in 2 cases only, in one case a malformed cord extended right down to the sacrum where it ended in a lipoma within an occult meningocele and in the other there was vertebral schisis at the same level as an intramedullary dermoid The bone changes of congenital tumours do not differ in tumour type but their incidence does Analysis reveals that in lipomas especially if extradural bone changes are infrequent (4 out of 10) while the reverse is the rule in dermoids epidermoids and teratomas (8 out of 9 cases)

Myelography Myelography was performed in 18 cases The contrast medium indicated the tumour site and its position with reference to the spinal cord and the dura in every case but yielded no information as to type The examination disclosed definitive block in 15 cases (83 %) The cerebrospinal pathways were clear in 3 cases of lipoma

Conclusions

Congenital tumours represented 5 % of all the tumours of the spinal cord The largest group was that of the lipomas followed in descending order by dermoids epidermoids and a teratoma The age at diagnosis was however in the reverse order beginning with the teratoma and ending with the lipomas the extradural variety being last of all Congenital tumours were found more often in the distal parts of the cord 7 lying in the conus medullaris

Bone changes in the lipomas were relatively infrequent but the rule in the other types Association with other malformations of the spine and cord was rare in the present series Myelography located the tumours but did not disclose their nature

SUMMARY

Nineteen congenital tumours of the spinal cord were studied Bone changes were observed in 12 cases (63) and were infrequent only in extradural lipomas Calcifications were observed in 2 cases Other associated malformations of the spine and cord as well as the value of myelography are discussed

as intramedullary tumours even at operation Their distribution was dorsal in one case, dorsolumbar in 3 cases, and lumbar and sacral in one case each, they may also be found in the cervical region The growths nearly always occupy the dorsal aspect of the spinal cord, as in the present cases The average age of the group was 36 years

Extradural lipomas These are often associated with an angiomatous component as in 3 of the 4 cases It is thought that they arise from bipotential mesenchymal cells about the adult capillaries that may develop into either blood vessels or fat (EHNI & LOVE 1945) These tumours present a more acute clinical symptomatology than intradural lipomas and, being clearly demarcated from the surrounding areas of extrathecal fat, can usually be easily removed They may be present anywhere along the spine but have a distinct preference for the dorsal region, the site of all the 4 cases Extradural lipomas are observed later in life than the intradural variety, the average age of our patients being 51 years

The *dermoids*, *epidermoids* and *teratomas* form a group of allied tumours that have often been confused, probably because of their gross similarity

Dermoids Dermoids are demarcated by a capsule of well differentiated stratified squamous epithelium and contain hair, sebaceous glands and other appendages of the skin All 5 cases were intradural and 4 were intramedullary Their locations were 2 dorsal, 2 in the conus medullaris, and one lumbar The average age of the patients was 21 years and 4 of the 5 were males

Epidermoids The tumour capsule encloses a mass of desquamated cells containing keratohyaline Known also as pure cholesteatomas or pearly tumours, they occur much more frequently in the brain than in the spinal cord Thirty one cerebral and 5 cranial epidermoids were operated on during the same period The 3 epidermoids of the spinal cord were in the conus medullaris or in the cauda equina The average age of the patients, all males, was 12 years

Teratomas These are derived from the three germ layers and may be distinguished from dermoids by the presence of muscle, cartilage and other mesodermal tissues The tumours have a definite predilection for the distal parts of the spine, especially for the sacrococcygeal region, when they occur in this situation they usually extend into the pelvis also and cause obstructive symptoms attributable to the rectum and ureters The teratoma observed in a 5 month old female child was lumbosacral and calcified This tumour has a predilection for females and sometimes becomes malignant

Bone changes were present in 12 cases (63 %) These were mostly confined to one or two vertebrae and were of the type usual in very slow growing

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CONTRAST EXAMINATION OF THE SPINAL EPIDURAL SPACE

by

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The epidural or peridural spaces which lie between the dura mater and the walls of the vertebral canal may be examined in the lumbosacral region by means of peridurography The dural sac tapers below into the filum durae matris spinalis which lies in the sacral canal The peridural space contains spinal nerves and blood vessels embedded in areolar connective tissue and fat and is connected with the paravertebral and presacral connective tissue via the intervertebral foramina connective tissue in these openings attaches the spinal nerves and blood vessels to the walls of the foramina (Charpy s ligament) Furthermore the peridural space is connected with the subcutaneous tissue via the sacral hiatus

The size and shape of the peridural space is determined by the manner of attachment of the dural sac to the walls of the spinal canal for example by the spinal nerves According to some authors the connective tissue on the ventral aspect of the dural sac is denser than elsewhere and may also provide some degree of fixation to the corresponding wall of the spinal canal There is no suggestion in the literature of any fixation to the dorsal wall

Peridurography is performed by the injection into the peridural space

ZUSAMMENFASSUNG

Neunzehn angeborene Tumoren des Ruckenmarkes wurden untersucht In zwolf Fallen (63 %) wurden Knochenveranderungen gefunden nur in extraduralen Lipomen waren diese selten Verkalkungen wurden in zwei Fallen festgestellt Begleitende Missbildungen der Wirbelsaule und des Ruckenmarkes sowie der Wert der Myelographie werden besprochen

RÉSUMÉ

Les auteurs ont étudié dix neuf tumeurs congénitales de la moelle Des signes osseux ont été observés dans 12 cas (63 %) ils ne sont rares que dans les lipomes extra duraux Il y avait des calcifications dans 2 cas Les auteurs examinent l association de ces tumeurs avec d autres malformations du rachis ou de la moelle et la valeur de la myelographie

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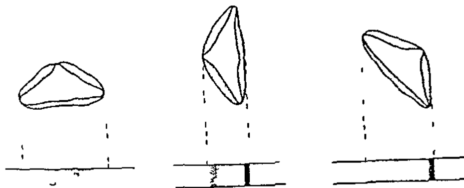


Fig 2 Contrast medium in the peridural space (dotted areas) in a p (p a) lateral and oblique projections White line in midline of a p projection corresponds with the dorsomedian dural fold A lighter central area separates the wider dorsal from a narrow ventral contrast band in the lateral view while one of the dorsolateral contrast bands appears as a narrow strip in the oblique film

the intradural pressure is lowered and due to this dorsomedian fixation forms a median fold this can be observed at operations in the lumbosacral area The same thing occurs when the pressure in the peridural space is elevated for example when contrast medium is injected, the ventral and both dorsolateral aspects of the dural sac will be expanded so that the sac is moulded into a more or less triangular cross section with the dorsomedian fold lying superiorly

This was clearly shown by post mortem studies following the injection of a barium gelatine mixture into the sacral hiatus Roentgenograms demonstrated a distribution of the contrast medium identical to that obtained in clinical examinations The vertebral column was then removed, sectioned and examined roentgenographically and by means of dissection This study confirmed the expansion of the contrast medium with formation of the dorsomedian dural fold at the lower lumbar levels (Fig 1) The projection of the peridural contrast medium in a p (or p a) lateral and oblique views is illustrated in Fig 2 The contrast medium in the lateral peridurograms is spread in a thin layer between the dural sac and the ventral wall of the spinal canal (Fig 3) This indicates that the peridural space lies in a more or less frontal plane between the dural sac and the ventral wall of the spinal canal and that its dorsoventral dimension is narrow This distribution is not uniform dorsal to an intervertebral disk it is small but behind a vertebral body it is usually larger increasing at every segment toward the centre of the latter

The dorsal aspect usually has a sharp borderline with a lighter central zone dorsal to which it passes into the wider dorsal contrast band It is thus obvious that at the level of the lighter mid zone the dimension of the peridural space



Fig 1 Autopsy in a 2 year old child Barium Indian ink gelatine mixture injected peridurally Cross section of vertebral column at level of lumbosacral disk Dorsomedian dural fold clearly demonstrated after some of the peridural gelatine mass has been removed The dural sac is moulded into a triangular form

through the sacral hiatus of 20 ml of a water soluble contrast medium, generally sodium diatrizoate No blood or cerebrospinal fluid must have escaped from the needle during the previously performed Valsalva manoeuvre Furthermore, the midline position of the tip of the needle not above the level of S 3—4 must have been checked by a p and lateral roentgenograms These precautions will ensure that the contrast medium is not injected into the subarachnoid space (vide infra) The medium usually reaches the upper lumbar or lower dorsal region It is absorbed in 30 to 45 minutes and excreted by the kidneys

Normal appearances of the lumbar peridural space

The shape of the peridural space is determined by the manner in which the dural sac is attached to the walls of the spinal canal The attachment is effected on the ventrolateral aspect by the spinal nerves but anatomic and surgical investigations revealed that the sac in the lumbosacral region appears to have another point of fixation in the median plane on its dorsal aspect where it is attached to the vertebral arches The sac more or less collapses if



F g 4 Fem le ged 32 with low back pain rad t ng i to both leg D min hed eflexes e pec lly of Ach lles tend n on right s de A p per durogram Central contrast column w th l ght m dl ne pe i ad cular ext ns ons of the cont ast med um bey nd the nterve tebral foram n except g on r ght id at le l of L 5—S 1 (I)



F g 5 Male aged 0 with low ba k pain rad ating nto left leg hypoton a of left quad r ceps and d m nished left patellar reflex Per durogram obl que Dorsolaterally located contrast med um ly ng n same d rection as cent al beam In front the em ning med um is part ally interrupted at L 3—4 (confirmed te of a protrud g d sk)

the central ray (Fig 5) this strip at the side of the vertebral bodies is bordered by a lighter zone by which it is *separated* from a wide band of medium intensity

The periradicularly situated contrast medium often extends into the para vertebral areas and there is apparently no discontinuity between the peridural space and the paravertebral regions Charpy s ligament not acting as a barrier



Fig 3 Female aged 29 with left radicular ischialgia and diminished reflexes on same side Lighter midzone between the ventral and the broader dorsal contrast band in lateral peridurogram ventral contrast band interrupted at L 4—5 (B) and dorsal contrast band curved backward (Operation Large protruding disk at L 4—5 mainly on left side)

is small With the localization of the dural sac within the spinal canal and its anchoring by the spinal nerves to the lateral regions of the spinal canal in mind, there is justification for considering the compressed dural sac responsible for the central zone

It may be assumed from the width and intensity of the dorsal contrast band that the peridural space is larger in size in the dorsal than in the ventral region of the spinal canal although its exact dimensions cannot be evaluated from lateral peridurograms alone

An a p peridurogram usually reveals a central contrast column (Fig 4), denser in the lateral than in the central zone A further continuation of the contrast medium along the spinal nerves can be seen passing through the intervertebral foramina (periradicularly) and running laterally and caudally A narrow strip is usually evident in the mid zone of the central contrast column and, as already explained, is due to the median fold of the dural sac in the dorsal region of the peridural space (plica mediana dorsalis) The 45 degree oblique peridurograms usually reveal a relatively narrow intense, sharply outlined strip along the side of the vertebral laminae that lie in the same direction as

care must be exercised because the dural sac may extend to an abnormally low level

Painful cramps occurred in only 6 cases of the present material, all of which recovered completely No other complications were encountered

The recommendation having been made that lumbar puncture should be performed only after peridurography the question has arisen whether the peri durally injected contrast medium may bring about changes in the composition of the lumbar spinal fluid An investigation was therefore performed in two groups of cases In the first group of 13 cases the composition of the spinal fluid was examined at various times before and after the peridurography in the second group of 8 cases the same procedure was carried out twice after the peridurography This study revealed no essential changes in the spinal fluid A slight increase in the total protein content was demonstrated in about a third of the cases but with the exception of one case no changes in the cell content were established

Present investigation

The investigation was performed in 600 cases The examination was un successful in a number of cases (7 5 %) the sacral canal being either too narrow or the hiatus could not be entered because of abnormal ossification in some of the cases while in others the puncture needle entered a vein and the contrast medium was injected intravenously In a few cases the investigation was unsuccessful because of a deformity of the roof of the sacral canal either it was not ossified or the hiatus was unusually high In the remaining unsuccessful cases the contrast medium rose insufficiently high into the lumbar region and a large part escaped through the sacral foramina

It is to be expected that in a number of pathologic conditions of the lumbar spinal and sacral canal changes will take place in the normal size and shape of the peridural space It need hardly be stated that this applies to prolapse of the intervertebral disk developmental narrowing of the lumbosacral vertebral canal peridural and/or periradicular adhesions and sacral perineural cysts These abnormalities often result in ischialgia of a radicular character together or without other radicular signs Evidence of either the orthotic cauda syn drome or compression of the cauda equina fibres is sometimes present Although the clinical signs of disk prolapse are sometimes so definite that there is no great need for radiologic investigation with contrast medium there are cases in which the latter is of great importance Peridurography is indicated when the diagnosis is still uncertain after clinical neurologic and supplementary radiologic examinations have been performed The cases in the present material

It is assumed in the literature that a barrier effect increases with increasing age, so that according to some authors (e.g. BROMAGE 1954) there is even a chance of complete impermeability. This is of importance with regard to effecting peridural anaesthesia. The peridurograms were used to make a study of the communication between the peridural space and the paravertebral area in the various age groups. No definite evidence of an increased barrier effect in older subjects was found. The impression was obtained, however, that in the lumbar and lumbosacral intervertebral foramina the barrier effect increases somewhat at more advanced ages, although this does not hold to any extent for the anterior sacral foramina.

Complications. It is necessary, as has been mentioned, by taking suitable precautions, to avoid introducing the contrast medium into the subarachnoid space. Reports in the literature and our own experience (in patients and experimental animals) have shown that this false injection may produce, shortly after its exhibition, intense painful cramps that may be accompanied by a state of severe shock.

Urografin 60 % was injected into the subarachnoid space in 14 cats weighing from 2.5 to 3.5 kg. It generally produced cramps but this appeared to depend upon the dose. No cramps were observed after the injection of 0.1 ml Urografin. When 0.2 ml or more was injected severe cramps, which caused the death of the animal, occurred. These could be prevented by an intraperitoneal injection of 120 to 240 mg Nembutal during the period of paroxysm: the cramps stopped and the cats recovered completely. There appeared to be a certain interval of time between the subarachnoid injection and the moment the cramps occurred. The length of this interval depended upon the amount of material injected. 0.2 ml caused cramps after about 15 minutes whereas 0.3 ml produced the paroxysm after 2 to 3 minutes. Another difference was observed when the results of suboccipital and lumbar injections were compared: the cramps after suboccipital injection started in the fore limbs and the neck, whereas lumbar injection produced paroxysms starting in the hind limbs, the tail and the caudal part of the rump.

Different amounts of methylglucamine (146.25 mg/ml) were also injected into the subarachnoid space in another series of cats. No cramps could be produced by this solvent.

Prompt intravenous infusion with a small dose of sodium Pentothal continued during the entire period of any tendency to symptoms produces complete alleviation. The chances of this complication are reduced by not performing a lumbar puncture for at least two, preferably three weeks, prior to peridurography.

The precautions mentioned previously reduce the chance of entering the caudal end of the dural sac or the radicular sheaths or perineural cysts originating from them to a minimum. The possibility of structural anomalies within the vertebral and sacral canal must be taken into account in the presence of marked signs of status dysraphicus. Under such circumstances the greatest



Fig 7 Male aged 63 with low back pain radiating into front of right thigh and calf dysbasia and patella reflexes diminished Normal lateral palpation on both sides Peridurography Indentations of dorsal contrast bands at arches of L 4 and L 5 Operation Narrowing of vertebral canal at cranial ridges of arches of L 4 and L 5



Fig 8 Female aged 45 with right radicular ischialgia paresis of right peroneal tibial muscles and some urinary retention Peridurography Contrast column interrupted at L 4—5 especially on right side (IIIa) round contrast filled and contrast free areas Operation Protruding disk at L 4—5 dural sac compressed by cranial ridge of arch of L 4 perineural cysts of 2nd and 3rd sacral nerves

veins peridural and/or periradicular adhesions spina bifida occulta, hypertrophy of the ligamentum flavum sacral perineural cysts and spondylolysis

The composition of these groups was selected wherever possible so as to exclude conditions complicated by other abnormalities The problem presented by this formation of pure groups is that the material for some conditions was very limited and so might preclude reliable statistical treatment In

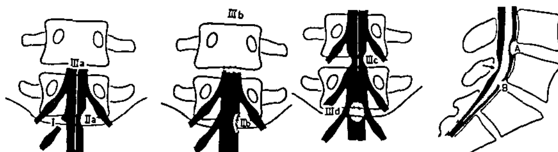


Fig. 6. Schematic representation of basic changes

except for about a hundred cases during the early period of the study, were treated according to these principles. Peridurography was carried out in the excepted group of cases when there was any suggestion of radicular ischialgia, in order to collect data.

A number of basic patterns that either alone or in various mutual combinations represent radiologic abnormalities were established for a closer study of peridurograms. These patterns were derived from both a.p. and lateral peridurograms. Each basic change was indicated by a code number (in the a.p. film: I, IIa, IIb, IIIa, IIIb, IIIc, IIId, and in the lateral film: A and B). This has made it possible to analyse every identified peridurographic abnormality in terms of one or more basic changes and to indicate it with a code number or a combination of such numbers (Fig. 6).

In addition to the changes produced by combinations of these basic patterns, several others characteristic of particular abnormalities appear. An indentation of the dorsal contrast band is observed at the site of the malformation in cases of developmental narrowing of the vertebral canal (Fig. 7). A marked increase in the width of the ventral contrast band, more or less triangular in shape, also appears at the site of the displaced vertebra in spondylolisthesis. Perineural cysts in the sacral canal may be evident in the a.p. peridurogram either as more or less rounded, contrast filled or contrast free areas in the sacral contrast column, the latter being more frequent than the former (Fig. 8).

The frequency of the different basic patterns was determined as part of a detailed study of the peridurographic changes that accompany the conditions studied. This was calculated according to the number of levels at which peridurographic alterations were observed. Only those cases in which confirmation at operation was possible were included in the group of conditions that were studied in more detail. These conditions consisted of prolapsed intervertebral disk, protruding disks with osteochondrotic lipping of the bone, developmental narrowing of the lumbar vertebral canal, dilated peridural

summarized as III but this does not obtain This should probably be ascribed to the fact that a disk prolapse with a predominantly lateral localization is often accompanied by a threshold formation extending over the entire width of the affected intervertebral disk The difference became more accentuated when the comparison was limited to a subgroup in which operation demonstrated strikingly large prolapses

If comparison be made with a group of prolapsed disks with osteochondrotic bone lipping only small differences are observed A markedly higher frequency is found only for IIIc (40 7 %) which statistically is on the borderline of significance Basic patterns IIIb and IIId are not present in this group The importance to be attached to this fact is hard to estimate without indulging in speculation

In the group of developmental narrowing of the lumbar vertebral canal the highest frequencies are found for basic patterns I, IIIa, IIIb IIIc and A The characteristics of this group become more marked after elimination of the basic patterns due to complicating changes

Basic pattern I appears to have a lower frequency than in the two preceding groups (46 2 %) This difference is significant as is the combination of I with IIa (5 1 %) The frequency of combination I with IIb on the contrary is not significantly different for either group If this comparison be extended significantly higher values are found for IIIa and IIIb (28 2 and 48 7 % resp) but for IIa an appreciably lower figure (7 7 %) which differs significantly from both preceding groups is reached To a lesser degree a similar difference which is however not significant can be demonstrated for B If compared with disk prolapses with osteochondrotic bone lipping this difference in the frequency of B is significant however

Since the development narrowing of the vertebral canal usually occurs over the entire width of the vertebral lamina the frequent occurrence of IIIa IIIb and IIIc is even less surprising than the lower frequency of I, IIa and B In addition to these differences attention has also been given to abnormalities of the dorsal contrast band at the level at which the vertebral arch exerts pressure and in particular to the dorsal indentation, which is considered of great importance The presence of this abnormality almost certainly points to a developmental narrowing of the vertebral canal

The fourth group that is considered to be sufficiently large to allow a more detailed analysis comprises peridurographic changes associated with peridural and/or periradicular adhesions as compared with the group of prolapsed disks The process of elimination was again applied In general corresponding frequencies could be established for many basic patterns A significant difference is evident for basic pattern IIb (22 9 %) while no great importance may

Table

The more frequent basic patterns and their mutual combinations in four groups of abnormalities studied in greater detail. The figures give the percentile frequencies. Values of 11% and higher in bold type, frequencies which differ significantly in italics

Abnormality	I	IIa	IIb	IIIa	IIIb	IIIc	I+IIa	I+IIb	I+IIIc	A	B
Disk prolapse	73.8	33.0	8.7	4.9	10.7	23.3	30.1	5.8	20.4	35.0	27.2
Disk prolapse with osteochondrotic bone lipping	70.4	37.1	11.1	3.7	—	*40.7*	29.6	7.4	33.3	35.9	40.7
Developmental narrowing of the vertebral canal	*46.2*	*7.7*	7.7	*28.2*	*48.7*	30.8	*5.1*	2.6	28.2	30.8	*12.8*
Peridural/periradicular adhesions	60.4	33.3	*22.9*	4.2	16.7	16.7	22.9	14.6	16.7	29.2	22.9

view of the method used, an exception was made in a number of groups. The groups comprising developmental narrowing of the lumbar vertebral canal and of the peridural and/or periradicular adhesions were thus given more detailed study not only in the 'pure' cases but also in those with complications, in the latter an elimination procedure was applied by which the frequency of the entire group was reduced by subtracting those which could be considered as caused by complicating abnormalities.

The results of the peridurographic analysis of the various groups were compared, especially with the group of disk prolapses, and the differences were examined statistically for significance (see Table).

For the group of uncomplicated prolapsed disks, the highest frequencies were found for I (73.8%), IIa (33.0%), IIIc (23.3%), A (35.0%) and B (27.2%). Of the other basic patterns only IIb and IIIb stood out with values of about 10%. The most frequently seen combinations were I with IIa (30.1%) and I with IIIc (20.4%), as well as I, IIa and IIc with A and B.

Basic patterns A and B were never present as single abnormalities when the a.p. peridurogram presented no changes.

The peridurographic alterations seem to be independent of the disk from which the prolapse developed. Appreciable differences appear, however, to exist between prolapsed disks with a lateral location and those which have no predominantly lateral localization. As could be expected, in the former group I and II are outstanding, with significant values for I (82.6%) and IIa (43.4%).

In the second group the same might be expected for the basic changes

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required to study this phenomenon Marked abnormalities as were already evident peridurographically, were present in all these cases however at nearby levels at surgical exploration No case in which peridurography had revealed changes was found *to* be *normal at operation* Restricting the cases to those with peridurographic findings at levels at which surgery revealed none — as against adjacent areas in the vertebral canal — the following may be emphasized

Only basic pattern A was evident in some cases in which the alteration was probably *still within the limits of normal variation* It is essential in individual cases that this basic pattern when present alone be interpreted with extreme care Basic pattern IIIc was evident in 3 cases but was not very distinct Surgery in all the cases revealed marked quantities of fat especially predurally this finding was noted in the surgical report which is exceptional It therefore *seems most* probable that the fat explains the peridurographic abnormality Peridurographic changes at one side of the vertebral canal in which the contrast medium had not risen normally because of unilateral obliteration of the peridural space at a lower level were described in some other cases The value of the peridurographic findings is evidently very dubious

Apart from six other cases in which only slight peridurographic changes together with normal distribution of the contrast medium were evident three other cases with definite unilateral abnormalities (basic pattern I) in which contrary to expectation operation provided no explanation must be recorded

In summary it may be stated that myelography was inadequate in a number of cases in which peridurography was able to provide reliable information This is undoubtedly dependent upon the special limitations caused by the dural sac In *addition peridurography offers diagnostic possibilities in numerous* conditions that cannot or cannot adequately be demonstrated by myelography (e g peridural adhesions developmental narrowing of the vertebral canal) On the other hand a number of peridurographic abnormalities have to be interpreted critically which means that the method to be of use unquestionably requires more experience than myelography

SUMMARY

Peridurography a *method of examination that* ind cates the shape and size of the peridural space at the lumbosacral level of the spinal canal is described It was found that it could be superior to myelography The method is particularly important in cases of disk prolapse pe idural adhes ons osseous stenosis of the vertebral canal *and* perineural sacral cysts

be attached to the higher frequency of IIIb (16.7 %). The frequency of the combination of I with IIb reveals no significant difference when compared with the other groups; in this group, B of the single lateral basic patterns is present when no abnormalities are evident in the a.p. peridurogram at the same level.

Basic patterns A and B are less frequently seen in the subgroup of the uncomplicated cases. This holds particularly for A, for which the difference with the disk prolapse group is significant.

The most striking frequencies of the basic patterns and their combinations for the four groups described are evident from the Table presented.

Sacral perineural cysts for the greater part appeared to be located at the second and the third sacral nerves and varied in size from a pea to a pigeon's egg. Apart from the peridurographic changes already described, the diagnosis may sometimes be made radiologically without contrast media if the cysts have produced pressure atrophy of the sacrum. A communication between the perineural cysts and the subarachnoid space could sometimes be established.

Finally, a group of exceptional cases must be mentioned. These cases include a number of tumours, originating from intradural, vertebral and paravertebral tissue, three cases of epidural cysts, and a case of spondilolysthesis, as well as a case of subdural haematoma.

The results of peridurographic and myelographic examination could be compared in 72 cases. Forty-eight of these were operated upon so that the radiologic and surgical findings could also be compared. In 35 of them the myelography and the peridurography gave different results. The operative findings did not agree with the results of the myelographic investigation, but in all but 4 cases there was agreement with the peridurographic findings. In 3 of them a second abnormality at a lower level had blocked off the peridurally injected contrast medium; in the fourth case a slight abnormality (IIb) was evident for which no surgical finding was reported. The inadequacy of the myelographic investigation, apart from 18 out of 31 cases of disk prolapse, especially concerned developmental narrowing of the vertebral canal, peridural and/or periradicular adhesions, and dilated peridural veins.

In all of the cases that were treated surgically, the peridurographic method provided insufficient information in only 2.9 %. This, without exception, can be ascribed to other abnormalities caudal to the involved level, such as a very prominent disk prolapse, developmental narrowing of the vertebral canal, or, as in reoperation, extensive peridural adhesions. These anomalies preclude further ascent of the contrast medium.

On the other hand it is doubtful whether at the level at which surgery revealed no pathologic findings changes were really evident at peridurography. Such cases have actually been encountered (4 %) and further analysis is

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ZUSAMMENFASSUNG

Peridurographie ist eine Methode, die die Form und Grosse des Periduralraumes der Lumbosakralgegend aufzeigt. Es wurde gefunden, dass die Methode der Myelographie in gewissen Fällen überlegen ist; *sie ist von besonderer Bedeutung beim Diskprolaps, bei* periduralen Verklebungen, knocherner Stenose des Wirbelkanales und bei perineuralen Sakralzysten.

RÉSUMÉ

Description de la péridurographie, méthode d'examen qui montre la forme et les dimensions de l'espace épidural dans la région lombo-sacrée du canal rachidien. Elle peut etre supérieure à la myélographie. Elle est particulièrement utile dans les cas de prolapsus discal, d'adhérences épidurales, de sténose osseuse du canal vertébral et de kystes sacrés périneuraux.

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LES HEMANGIOMES DU RACHIS CERVICAL

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La symptomatologie radiologique des hemangiomes vertebraux est bien connue et pratiquement pathognomonique striation longitudinale du corps, legere deformation eventuelle de celui ci aspect parfois ponctue des pedicules et des lames lorsqu ils sont entrepris Il est aise de les reconnaitre Nous nous proposons d etudier ici certaines lesions du rachis etiquetees hemangiomes dont l aspect radiologique est different et prete a confusion Il s agit de tumeurs developpees au niveau de la colonne cervicale constituant des cas limites d interprétation difficile s accompagnant de complications graves

Les hemangiomes vertebraux sont le plus souvent localises aux niveaux dorsaux et lombaires et preferentiellement a la charniere dorsolombaire Cette rarete relative de l hemangiome cervical est illustree par les statistiques de Schmorl (584 cas dont 32 localisations cervicales) de Holta (40 cas dont deux cervicaux) de Topfer de Stettbacker (104 cas dont 5 cervicaux) de Sherman et Wiener (14 cas dont 1 cervical)

Cette disposition s expliquerait par la vascularisation rachidienne Celle ci est assuree par deux plexus intra et extra rachidiens qui communiquent largement par les trous de conjugaison par les espaces situes entre les lames et au travers des corps vertebraux Cette vascularisation n est pas d egale

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Fig 1 Cas 1 a) Hemangiome de C4—C5 Asp ct de la lésion lors de son depistage rad ol gique b) Tom graphie Rétrecissement du canal medi llai e en C2—C3

L amelioration se poursuit durant 8 mois environ puis la quadriplégie réapparait progressivement sans que l image radiologique ne soit modifiée

Une traction continue est réinstallée durant 10 mois en outre au cinquième mois de traction et sans que celle ci ne soit interrompue une large intervention décompressive cervicale est réalisée Elle est associée a la mise en place d une greffe osseuse prelevée a la crete iliaque allant de C6 à la protubérance occipitale externe et immobilisant la colonne cervicale L intervention chirurgicale permet de constater un épaississement des éléments vertebraux responsables d un notable rétrécissement du canal rachidien Des la traction installée les troubles neurologiques régressent progressivement en meme temps que le segment patholo ique du rachis s allonge et se redresse

La radiothérapie est reprise des la fin du traitement par traction la do e totale administrée s elevant à 2 700 R profonds

L amelioration des troubles neurologiques se poursuit peu a peu en meme temps que la recalcification des lésions Le greffon est parfaitement toléré La décalcification des vertebres sus et sousjacentes au bloc a cependant progressé (Fig 3)

Revue 4 ans plus tard la patiente conserve quelques troubles neurologiques et une immobilisation gênante du cou par la greffe osseuse Elle se déplace seule et peut vaquer à ses occupations sans t op de peine

2 *Deu ieme observation* La patient agé de 45 ans est admis pour un syndrome quadriparéti que évolutif (1963)

A l age de 22 ans il avait été pris dans un éboulement de la mine dont il fut retiré quadri plégique Les adiog aphies de la colonne cervicale ne mirent cependant aucune lésion osseuse en év dence La récupération s installa apres deux mois et fut lente Elle permit

importance au niveau des divers segments rachidiens. Elle augmente progressivement à partir des premières vertèbres cervicales et présente son maximum au niveau de la charnière dorso-lombaire. Elle décroît brusquement au niveau des vertèbres sacrées (REBOUL).

En 1933, HEANEY et WHITAKER décrivent le premier cas intéressant une vertèbre cervicale. Puis GESCHICKTER et KEASBEY en 1935, rapportent le premier cas d'hémangiome cervical prouvé histologiquement et ayant provoqué une compression médullaire avec paralysie : les corps des 4e, 5e et 6e vertèbres cervicales étaient entrepris par le processus. SCHLEZINGER et UNGAR, JACOBOVICI, GHORMLEY et ADSON, HOLTA, et BROBECK décrivent chacun une observation d'hémangiome d'une ou plusieurs vertèbres cervicales. Enfin GURI, BIEMOND, COCCHI, GUNTERT, ROBINS et FOUNTAIN ont rapporté depuis 1948, les observations de cinq cas d'hémangiomes cervicaux ayant entraîné une compression médullaire, complication dont nous n'avons retrouvé que 11 cas rapportés actuellement au niveau cervical. Un angiome des tissus mous du cou peut présenter une extension intraspinale : PYGOTT et HUTTON l'ont prouvé par artériographie.

Exposé des cas

I. *Première observation.* A l'âge de 39 ans, cette patiente ressent un craquement douloureux de la colonne cervicale lors d'une flexion forcée de la nuque au cours d'une séance de gymnastique. Les radiographies montrent : une cyphose cervicale haute, une décalcification et une déformation de C2 et de C3 dans leur totalité. La trabéculation est grêle et relâchée ; elle se présente sous la forme d'un réseau à larges mailles. Le disque intercalaire n'est pas visible. Les apophyses épineuses, les lames sont partiellement soudées. L'inclinaison de l'apophyse odontoïde est exagérée vers l'avant. La texture de l'atlas est conservée. C4 et C5 sont assez peu calcifiées mais leurs limites sont nettes ; les apophyses articulaires supérieures de C4 sont entreprises par le même processus que celui décrit en C2—C3. Le corps de C4 est décalé vers l'arrière par rapport à C5. Les rebords des corps de ces vertèbres portent des ostéophytes. La largeur de l'espace pré-vertébral est normale (Fig. 1).

La tomographie sagittale (Fig. 1 b) confirme la description ci-dessus. Elle définit en plus un rétrécissement notable du canal médullaire en C2—C3. Le bord postérieur des corps de C2—C3 forme une voussure importante à convexité postérieure.

Deux ans plus tard, après s'être cogné la tête contre un mur, la patiente développe une quadriplégie spastique. Des contrôles radiographiques mettent en évidence une accentuation des lésions. Le processus s'est étendu vers le bas aux corps de C4—C5 et vers le haut à l'atlas. L'espace pré-vertébral est élargi (Fig. 2). L'examen du reste du squelette (colonne dorsale, lombaire, crâne, épaules) ne met pas de lésion en évidence.

L'étude du métabolisme phospho-calcique s'avère normale. La biopsie de la lésion est en faveur du diagnostic d'angiome osseux.

Durant un an, un traitement par traction discontinue au moyen d'une mentonnière, puis par traction continue au moyen d'un étrier de CRUTCHFIELD est appliqué avec un résultat favorable. Il est complété par de la radiothérapie (dose profonde de 1.200 R) qui amène une certaine recalcification des lésions vertébrales.



Fig 4 Cas 2 Hemangiome de C2—C3



Fig 5 Cas 2 Temps arteriel de l angiographie vertebrale Il n y a pas de foyer évident de vascularisation pathologique de la lesion vertebrale qui parait cependant mieux visualisée que sur les clichés standards

L investigation biologique ne mit en évidence qu un taux elevé des phosphatases alcalines 11 8 unites Bodansky pour 100 ml lors d un premier examen et 9 6 unites lors d un controle une semaine plus tard Le liquide céphalo rachidien était de composition normale La vitesse de sédimentation était de 2 mm en une heure

Un traitement par RX fut instauré en meme temps qu un collier en plastique soutenait et immobilisait la colonne cervicale 2 500 R profonds furent delivrés en deux séries de 29 et 11 seances respectivement

Des controles radiographiques et neurologiques furent faits au cours des mois suivants et ne montrerent aucune modification notable des lésions bien que le patient manifeste une amélioration clinique discrète

Discussion

Nos deux cas posent de nombreux problemes tant au sujet de l interpretation radiologique que de l interprétation histologique Ils donnent lieu en consequence a discussion quant a l origine de la symptomatologie clinique et radiologique et encore au point de vue du traitement

Considerations radiologiques Lors d un angiome il existe habituellement une diminution legere de l opacité generale du corps vertebral L aspect le plus



Fig 2 Cas 1 Deux ans apres l examen represente par fig 1 l espace pré vertébral est élargi



Fig 3 Cas 1 Radiographie 4 ans apres laminectomie décompressive et pose d un greffon de C6 à la protubérance occipitale externe

finalement une reprise satisfaisante des activités professionnelles 3 ans apres l accident Six mois avant son hospitalisation le patient rate une marche d escalier et tombe de sa hauteur Cette chute bénigne entraine l installation brutale de la quadriplégie en meme temps que le patient accuse une sensation fugace de courant électrique dans le dos et le membre supérieur gauche La récupération des troubles moteurs se réinstalle une fois encore et débute par le membre supérieur droit pour gagner ensuite le membre inférieur droit Elle n est cependant que très lentement progressive et relativement peu importante

Au moment de son hospitalisation le patient se plaint toujours d une raideur de la nuque L examen met en évidence une quadriparésie spastique à prédominance hémiplégique gauche Les déficits sensitifs rappellent le syndrome de Brown Séquard Il existe des troubles sphincteriens

Les radiographies de la colonne cervicale montrent que C2 est fortement déformé en particulier au niveau de son apophyse épineuse qui est fortement tuméfiée (Fig 4) La trabéculation se présente sous la forme d un réseau irrégulier à mailles tres laches Ce processus s étend a l extrémité supérieure du corps de C3 Le disque C2—C3 n est pas visible Les corps les lames les apophyses épineuses de C2—C3 sont soudés

Les tomographies n apportent pas d élement diagnostique supplémentaire

Une angiographie vertébrale droite ne met pas de foyer de vascularisation pathologique en évidence avec certitude (Fig 5) bien qu il existe un certain degré de dolichoartère au niveau cervical Il n y a pas de foyer évident de vascularisation pathologique de la lésion vertébrale qui parait cependant mieux visualisée que sur les clichés standards

Une iodo ventriculographie montre simplement un ralentissement du produit de contraste au niveau du segment cervical supérieur

Une biopsie de l apophyse épineuse de C2 est pratiquée et a l examen anatomo-pathologique on observe des plages de remaniement fibreux de la trame medullaire et de nombreuses formations vasculaires limitées par un simple endothélium

secondaires et l augmentation d activité des osteoclastes le phenomene initial La relation entre angiomatose et ostéolyse massive a ete soulignee par GORHAM et STOUT en 1955 Ils ont pu etudier les preparations microscopiques de 8 parmi 24 cas qui avaient ete proccedemment décrits comme des osteolyses massives chacune des huit coupes leur a permis d infirmer ce diagnostic primitif et de le remplacer par celui d hemangiome osseux vertebral

Plus recemment TUCKER etudiant les lymphangiectasies a releve les dif ficultés qui surviennent au moment de differencier parmi les angiomatoses les hemangiomatoses des lymphangiomatoses Il démontre également les aspects d osteolyse massive qui s y apparentent

La possibilite de la localisation vertebrale d une dysplasie fibreuse a ete egalement envisagee Cette eventualite a eté signalee par LEDOUX LEBARD et SULTKIN reprise ulterieurement par JENSENS Selon LEDOUX LEBARD la dysplasie fibreuse pourrait se presenter sous l aspect d un type pseudo angio mateux et d un type pseudo pagetique Dans la premiere eventualite des stries verticales caracteristiques se retrouvent ainsi que de petite images en logettes Parfois se produit une soufflure du corps et de l arc posterieur L examen radiologique systematique du squelette est indispensable a la recherche d une autre localisation Cette etude evite une biopsie qui peut etre hemorragique La vertebre pseudopagetique e presente sous un aspect en cadre des zones de destruction et d eburnation peuvent alterner Le diagnostic est guide par l appreciation de l age et du sexe du patient et par la recherche d une autre localisation squelettique Neanmoins lorsque cette localisation est mono ostotique seule une biopsie permet de re oudre le dilemme D une maniere generale les examens de laboratoire au cours de la dystrophie fibreuse décele une augmentation des phos phatases alcalines celles ci dont l taux normal est de 4 passent a 17 a 22 unites Bodanski

Les images que nous avons decrites dans nos deux cas incitent encore a discuter l eventualite de tumeur primitive ou secondaire de tumeur a myelo plaxe d enchondrome de metastase d osteose fibro kystique para thyroidien ne de Recklinghausen de myelome localise de maladie de Hodgkin de réti culose benigne ou maligne de leucemie Bien souvent la biopsie permettra seule d eclaircir le probleme

L aspect de bloc présent dans nos deux cas est aussi a discuter S agit il d un bloc primitif ou secondaire? La question de l integrite de l espace inter vertebral au cours des hemangiomes est diversement interpretee par les auteurs Classiquement BROBECK (1950) considere que l espace est intact pourtant en 1919 TROMMER décrivait un hémangiome de D5—D6 ayant infiltre et detruit le disque intervertebral REBOUL et coll posent la question de savoir si la disparition du disque est une consequence de l angiome ou le resultat de

caractéristique cependant est constitué par la *présence* de stries verticales longitudinales bien appréciables de profil, sur la vue de face se présente habituellement une texture aréolaire. Le cortex du corps vertébral *peut* être légèrement mal défini, mais il est habituellement intact, (SHERMAN, REBOUL). *Dans nos cas, le* réseau trabéculaire est lâche, il n'y a pas de striation longitudinale ni de disposition aréolaire à petites mailles caractéristique.

Cet aspect rappelle plutôt la disposition loculée décrite par certains auteurs au cours du lymphangiome. COHEN et CRAIG ont présenté un cas de lymphangiome du rachis cervical dont l'aspect *est proche* de celui visible chez nos malades, tant par sa situation que sa texture. Le diagnostic *différentiel n'a* pu être résolu qu'après biopsies multiples et même vérification nécropsique. *La tumeur* s'était progressivement étendue de C2 à C6. Elle se caractérisait par une apparence bulleuse du tissu spongieux. Cette lésion pourrait correspondre à une *simple* malformation, à un néoplasme, à une infection. Elle pourrait encore être *secondaire à l'obstruction* de vaisseaux lymphatiques. Une autre éventualité a été envisagée, celle d'une ostéolyse massive ou maladie de Gorham.

Les ostéolyses ont été liées à des troubles neurologiques ou neuro-sympathiques apparaissant dans le cadre d'une ostéo-arthropathie tabétique, syringomyélique ou lépreuse, à des syndromes neuro-endocriniens complexes et à des polyarthrites ou à des *rhumatismes chroniques progressifs*, à des phénomènes post-traumatiques dans lesquels le phénomène *vasomoteur serait* le fait essentiel (LERICHE).

KAUFMAN a décrit un cas d'ostéolyse cervicale au contact d'une adénopathie *ayant guéri* par lymphadénectomie.

Le problème très touffu de l'ostéolyse massive a été étudié particulièrement par GORHAM et STOUT, ils ont schématisé la topographie squelettique d'après une série de 18 cas. Le degré de résorption osseuse correspondant au niveau de la colonne cervicale est modéré. Cette affection se développe habituellement dans l'enfance : 13 de leurs patients avaient moins de 21 ans. L'ostéolyse progressive est toujours associée à une angiomatose de vaisseaux sanguins ou lymphatiques *qui en paraissent* responsables. Pour JOHNSON et MCLURE, l'ostéolyse *massive représente* une variation d'angiomatose. *Elle présente* deux états pathologiques au moins : au début de l'affection se produit une prolifération capillaire intra-osseuse comparable à celle vue distalement à une fistule congénitale artério-veineuse. Plus tard, l'angiome devient fibreux, une avascularité *complète* est cependant rare et une calcification n'a pas été observée. Pour ABELL et BADGLEY, la prolifération vasculaire locale et l'hyperémie secondaire seraient à l'origine d'un déséquilibre de l'antagonisme entre ostéoblaste et ostéoclaste. Pour d'autres, les anomalies vasculaires seraient

stade, certains troubles de la sensibilite peuvent etre presents, qui prennent une topographie radiculaire a un stade d évolution ulterieure la symptomatologie est celle d une compression medullaire Pourtant il est impossible de brosser un tableau clinique précis de l hemangiome vertebral dont les conséquences symptomatiques multiples et variees sont fonction directe du degre d extension de l angiome et de l importance des lesions osseuses elles ne sont en realite pas differentes de toute affection tumorale de la colonne vertébrale

L evolution de la maladie est capricieuse et imprevisible le plus générale ment elle n entraine aucune complication et reste benigne ce n est que tres rarement que les troubles nerveux apparaissent Il semble qu on puisse ob server des poussees evolutives suivies de periodes de repos surtout chez les patients ages

Foster et Huebleiv ont classifie les angiomes vertebraux en quatre groupes (1) asymptomatiques (2) symptomatiques (douleur sans atteinte neurologique) (3) entrainant des signes de compression medullaire dus a l extension de l hemangiome dans l espace epidural (4) accompagnes de fracture pathologique de la vertebre avec ou sans signes medullaires

Cette classification rejoint celle de Reboul et coll qui envisagent quatre formes latentes patentes compliquees ou associees (a d autres angiomes visceraux cutanes ou osseux extravertebraux)

La symptomatologie clinique apparait lorsque l hémangiome affleure la surface osseuse et atteint la moelle (Holta) Celle ci peut etre lesee par la propagation de l hemangiome dans le canal spinal par pression due a la tuméfaction du corps vertebral ou des arcs par tassement de la vertebre envahie par hemorragie épidurale

Considerations therapeutiques Ces deux observations traitees differemment l une de l autre nous amenent a discuter du probleme therapeutique Celui ci est en fait fonction de plusieurs facteurs parmi lesquels la deformation de l axe vertebral et la compression du cordon médullaire sont les plus importants

L hemangiome vertébral surtout cervical peut se developper sous forme d une lesion osteoclastique predominante entreprenant une ou plusieurs vertebres Cette alteration de l architecture osseuse entraine alors des modifications plus ou moins graves de la statique vertebrale sous forme de courbures anormales a court rayon de tassement ou de subluxation

Si le malade est vu avant que les altérations osseuses ne soient trop prononcées et n entreinent de troubles neurologiques importants il peut etre traite par roentgentherapie seule pour autant que la précaution elementaire de protéger la colonne par un collier de soutien soit prise La radiotherapie en

phenomenes arthrosiques favorises par la presence de cet angiome JAFFE decrit des modifications plus ou moins importantes de l'espace intervertebral surtout lorsque deux vertebres voisines sont angiomateuses L'analyse de notre premier cas montre que les espaces intervertebraux ont subi un remaniement profond aboutissant a la formation d un bloc reunissant quatre vertebres cervicales

Ces problemes ont particulierement ete mis au point par DESEZE d une part, par MARCHANT et coll d autre part Enfin, l etude tomographique et pneumomyelographique d'un bloc vertebral cervical a ete effectuee par BONTE, NIQUET et CARON L hypothese de la degenerescence hemangiomateuse de malformations vertebrales a été retenue par certains auteurs l aspect fusionne de deux ou plusieurs vertebres resulterait du developpement d un angiome au niveau d un bloc vertebral d origine congenitale Leurs arguments ne nous ont pas paru convaincants, nous pensions plutot que le developpement de l angiome est primitif et que son extension entraine la formation d un bloc osseux s'etendant a plusieurs segments DESEZE reconnait le bloc congenital au parallelisme des plateaux de l extremite superieure et inferieure du bloc, a la regularite parfaite et à la rectitude des limites antérieures et posterieures du bloc, a la persistance d une image discale, a la synostose des arcs posterieurs des lames et des apophyses epineuses a la diminution de la hauteur des trous de conjugaison ainsi qu a leur forme arrondie MARCHANT insiste sur la présence de trous de conjugaison arrondis, leur surface laisse supposer que les racines qui y passent sont greles il s agirait embryologiquement d un defaut de segmentation

Dans les blocs acquis, la diminution de hauteur des corps vertébraux porte surtout sur leur partie anterieure et se caracterise par une convergence en avant des plateaux, par une voussure anterieure a la jonction des deux vertebres synostosees, à une angulation a sommet dorsal de la limite posterieure du bloc vertebral, a l absence de toute image discale, a l absence de soudure des arcs posterieurs, a la divergence des apophyses epineuses a la forme allongée des trous de conjugaison Ils s accompagnent souvent d antecedents infectieux qui sont a rechercher

Lorsque ces criteres sont appliques a nos cas, il parait s agir plutot de blocs secondaires que de blocs congénitaux La preuve en est donnée par une radiographie anterieure de notre cas 2 qui montre l absence de bloc vertebral antérieur, 23 ans avant le dépistage de l hémangiome

Considérations cliniques Au point de vue de la symptomatologie clinique le premiere plainte emise par le patient consiste en une douleur locale, associée a un spasme musculaire et a une rigidite segmentaire de la colonne Deja, a ce

RÉSUMÉ

Les hemangiomes vertébraux classiques sont aisement reconnaissables par leur aspect radiologique Leur symptomatologie clinique est absente fruste ou sévere Les statistiques montrent que leurs *localisations au niveau du* rachis cervical sont rares. Leur aspect radiologique prête souvent à confusion le choix s impose frequemment entre hémangiome lymph angiome ostéolyse blocs primitifs ou secondaires dysplasie fibreuse neoplasies primitives ou secondaires etc Ils entrainent fréquemment des complications cliniques extremement graves telles des quadriplégies. La thérapeutique soulève de nombreux *problèmes. Bien* souvent des biopsies même répétees prêtent a discussion et ne permettent pas d établir un diagnostic précoce Ces considérations sont etayees par l exposé de deux cas particulierement complexes

SUMMARY

The classic hemangiomas of the vertebral column are readily recognized from their radiographic appearances Clinical symptoms are either absent mild or severe Statistically they seldom occur at the cervical level They are often difficult to distinguish roentgenographically from lymphangioma osteolysis primary or secondary blocks fibrous dysplasia and primary or secondary neoplasms They often cause severe clinical complications such as quadriplegia and their treatment can be difficult Biopsy even if repeated several times does not always lead to a definite diagnosis Two difficult cases are described

ZUSAMMENFASSUNG

Die klassischen vertebralen Hamangiome sind radiologisch leicht erkennbar Eine klinische Symptomatologie mag nicht vorhanden sein aber kann auch mild oder ernstlich sein Statistisch werden sie selten auf dem Niveau der cervikalen Wirbelsaule lokalisiert Es ist oft schwer auf dem radiologischen Wege eine Differentialdiagnose zwischen Lymphangiomen Osteolysen primaren oder sekundaren Blocken und zwischen fribrosen Dysplasien primaren oder sekundaren Neuplasmen festzustellen Die Hamanghome sind oft mit schweren klinischen Komplikationen sowie mit Quadriplegie begleitet Die Therapie bietet zahlreiche Probleme Die Biopsie auch mehrmals wiederholt gibt keine klare Indikation und ermoglicht keine definitive Diagnose Zwei besonders schwierige Falle werden beschrieben

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effet paraît jouer un rôle efficace en déclenchant une certaine recalcification de la lésion

En plus des altérations osseuses rappelées ci dessus, l'hémangiome vertébral peut se développer sous forme d une lésion plus ou moins expansive, entraînant un accroissement de volume de la vertèbre et par conséquent une réduction des diamètres du canal rachidien

Il peut en résulter une compression du fourreau dural qui se rencontre aussi lorsque la statique de l'axe de la colonne vertébrale sont gravement altérés

Il nous paraît évident que la radiothérapie devient inopérante lorsque les troubles neurologiques sont provoqués par l'une ou l autre de ces deux causes et qu elle doit être précédée soit par une décompression chirurgicale du canal rachidien, associée ou non à une fixation de la colonne, soit par une traction continue

Il ne faut cependant pas se cacher que le blocage par greffe du segment cervical entraîne une impotence fonctionnelle fort gênante Par ailleurs l'abord de ces vertèbres fragiles n est pas sans risque d aggravation du tableau neurologique et doit se faire avec infiniment de précautions et de douceur Pour notre second malade par exemple, bien qu il existe une quadriparésie, nous n avons recourru qu a la seule radiothérapie, parce que l analyse cyto chimique du liquide céphalo rachidien était normale et que d'autre part la myelographie avait montré un simple retard du transit du produit opaque En outre, une lente amélioration clinique était en cours

Il nous paraît donc qu aucune attitude thérapeutique ne peut être fixée d'avance Celle ci sera fonction de l image radiologique, des troubles subjectifs (forme douloureuse) et de l examen neurologique

Conclusion

L hémangiome vertébral correspond à une lésion lentement évolutive qui peut s étendre progressivement a plusieurs vertèbres Il se complique souvent, au niveau cervical, d'une inflexion anormale de la colonne En outre, des traumatismes bénins peuvent occasionner des subluxations et des contusions médullaires Enfin, la distension de la vertèbre par le processus néoplasique peut aggraver la compression de la moelle

Le traitement à base de radiothérapie seule ou combiné soit a une traction continue, soit à une décompression du canal rachidien avec, ou sans fixation du segment vertébral, dépendra du tableau radiologique ou neurologique

RESUMÉ

Les hemangiomes vertébraux classiques sont aisément reconnaissables par leur aspect radiologique Leur symptomatologie clinique est absente fruste ou sévère Les statistiques montrent que leurs localisations au niveau du rachis cervical sont rares. Leur aspect radiologique prete souvent a confusion le choix s impose fréquemment entre hémangiome lymph angiome ostéolyse blocs primitifs ou secondaires dysplasie fibreuse néoplasies primitives ou secondaires etc Ils entrainent fréquemment des complications cliniques extrêmement graves telles des quadriplégies La therapeutique soulève de nombreux problèmes Bien souvent des biopsies meme répétees prêtent a discussion et ne permettent pas d établir un diagnostic précoce Ces considérations sont étayees par l exposé de deux cas particulièrement complexes

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SERVICE DE NEURO RADIOLOGIE DE L HOPITAL DE LA PITIE (PROFESSEUR H FISCHGOLD) ET CLINIQUE DE NEURO CHIRURGIE DE LA PITIE (PROFESSEUR M DAVID), PARIS, FRANCE

LA MYFLOBULBOGRAPHIE GAZFUSE DANS LES MYELOPATHIES CRONIQUES

par

J Metzger Ph Engel D Dilenge et J Aboulker

On connait mal la cause de certaines myélites ou de myélopathies provoquant des paraplegies ou des quadriplegies chroniques Nous pensons qu il s agit de maladies mécaniques d origine rachidienne liées à une sténose du défile cranio cervical ou du canal cervical

Pendant plusieurs années l un de nous (J A) a opére un certain nombre de ces malades sur des données cliniques sans examen de contraste depuis deux ans nous avons adapté la methode de Lindgren de myelographie gazeuse totale pour visualiser le bulbe mesurer les dimensions du canal mettre en évidence les stenoses et enfin montrer par une étude dynamique la réalité des traumatismes que subit le nevraxe lors des mouvements de la tete

Chaque intervention est donc maintenant précedée et suivie d une myélo bulbographie gazeuse

La technique

Nous pratiquons essentiellement des tomographies sag ttales en balayage hypocycloide le seul permettant d obtenir de bonnes images de la region cervico-dorsale Avec l appareillage ut lise qui comporte une table mobile pour la recherche du plan de coupe le coefficient d agrandissement est toujours le même égal a 1 35 et tous les clichés sont de ce fait compara bles

En général deux aiguilles sont utilisées, l'une sous occipitale pour retirer le liquide céphalo rachidien, l'autre lombaire pour injecter l'air. Une fois la soustraction du liquide terminée l'aiguille sous occipitale est retirée et de l'air est injecté par voie lombaire sous une pression correspondant à environ 40 cm d'eau au manomètre de Claude ce qui permet une véritable myélobulbographie gazeuse (Fig. 1).

Nous voyons en effet non seulement la moelle mais aussi le tronc cérébral ou sa partie inférieure, le 4ème ventricule, la citerne pré pontique, la grande citerne et le vermis.

Grace à l'aiguille lombaire conservée en place, l'hyperpression est supprimée dès que la prise des clichés est faite.

Quand une malformation entraîne une sténose de trou occipital rendant la ponction sous occipitale dangereuse, il est utile de faire précéder cette dernière d'une étude de la grande citerne. Dans ces cas on pratique la myélographie gazeuse totale uniquement par voie lombaire. Cette méthode dite de reflux consiste à injecter 7 à 8 ml d'air toutes les cinq minutes en contrôlant au manomètre de Claude la pression qui s'élève après l'insufflation à 55 cm d'eau pour retomber à chaque fois à 35 cm environ en 5 minutes.

La myélographie gazeuse montre sur les tomographies sagittales médiane et para médianes la tête étant dans ce premier temps en position indifférente, le cordon bulbo médullaire limité par des colonnes d'air antérieure et postérieure correspondant à l'espace sous arachnoïdien et qui dans certaines conditions s'amincissent et disparaissent. Or normalement cet espace sous arachnoïdien forme un coussin hydraulique qui protège la moelle de tout contact direct traumatisant avec les parois ostéo ligamentaires du canal rachidien.

Dans plusieurs de nos cas nous avons pratiqué des mensurations mais l'aspect des colonnes d'air antérieure et postérieure est souvent plus significatif que les dimensions du canal et du cordon médullaire.

Signalons qu'une myélographie gazeuse pratiquée chez des malades ayant déjà eu un examen par huile iodée est de lecture difficile du fait d'images d'adhérences et de superpositions gênantes.

Étude dynamique. Elle donne des renseignements complémentaires intéressants dans les cas de sténose. Les tomographies sont pratiquées après avoir placé la tête du patient en flexion puis en déflexion pour mettre en évidence le comportement du cordon médullaire au cours de ces différents mouvements : dans les sténoses cervicales les mouvements produisent des micro agressions sur le névraxe et sur les racines et ces traumatismes chroniques peuvent jouer un rôle déterminant dans la pathogénie d'une partie des maladies chroniques de la moelle cervicale et du bulbe.

Cette étude dynamique prolonge quelque peu la durée de l'examen et c'est la raison qui fait préférer l'injection d'air à celle d'oxygène dont la résorption est un peu trop rapide.

Resultats

Dans 48 cas, la myélobulbographie a mis en évidence 21 cas de sténose pure et 27 cas de sténose constitutionnelle du canal cervical, compliquée d'arthrose.

Sténoses cervicales pures, constitutionnelles, sans arthrose

Nous avons réuni sous ce titre tous nos cas de rétrécissement du calibre du canal rachidien n'ayant pas présenté d'arthrose ou de malformation osseuse associées. Elles peuvent se classer de la façon suivante :



Fig 1 Myélobulbog ph e gaz use n male Espace sous-a a hnoid en gul er et bien sible autour du bulbe et de la moelle Quelle que so t l étendue des mouv ments l ne ra e est protége de tout contact avec le canal pa un l rge espace sous-arachnoid en



Fig 2 Myelobulbographie Flex on Steno e du canal cerv cal etroit sur toute sa hauteur Espace sous arachno d en m nce en avant presque d sparu derr ère la moelle de C2 a C7 Femme de 50 ans Paraplégie sp smod que chron que p ogressive

Stenoses du defile occipito-cervical et du canal cervical (10 cas) Certaines formes comportent une stenose dysmorphique globale du canal cervical et du défile cranio cervical Le rétrécissement s étend du trou occipital jusqu a la charniere cervico-dorsale Le canal rachidien s élargit alors dans la région dorsale supé rieure

La myélobulbographie gazeuse montre dans 70 % des cas une moelle plaquée en avant contre le plan vertébro discal tandis qu une mince colonne d air est encore visible en arriere Dans les autres cas c est l inverse la moelle

En général deux aiguilles sont utilisées l une sous occipitale pour retirer le liquide céphalo-rachidien, l autre lombaire pour injecter l air Une fois la soustraction du liquide terminée, l aiguille sous occipitale est retirée et de l air est injecté par voie lombaire sous une pression correspondant à environ 10 cm d eau au manometre de Claude ce qui permet une véritable myélobulbographie gazeuse (Fig 1)

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Étude dynamique Elle donne des renseignements complémentaires intéressants dans les cas de sténose Les tomographies sont pratiquées après avoir placé la tete du patient en flexion puis en déflexion pour mettre en évidence le comportement du cordon médullaire au cours de ces différents mouvements dans les sténoses cervicales les mouvements produisent des micro agressions sur le névraxe et sur les racines et ces traumatismes chroniques peuvent jouer un role déterminant dans la pathogénie d une partie des maladies chroniques de la moelle cervicale et du bulbe

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Fig 5 Myelobulbographie Homme de 0 ans Paraplegie progressive et syndrome cerebelleux A gauche Canal cervical etroit a partir de C2 Mince colonne d air antérieure et posterieure A droite Controle postopératoire Craniotomie sous occipitale et laminectomie de C1 a D? Reconstitution d un espace sous-arachnoidien de dimensions normales



Fig 6 Myelobulbographie Stenose du defilé cranio cervical Disparition quasi totale de l espace sous arachnoidien et de la grande citerne Un eperon ligamentaire et dure mere en supprime l entonnoir cranio-cervical habituel Femme de 36 ans Paraplégie progressive et troubles de la voix

L étude dynamique dans ces cas montre le role défavorable de la deflexion qui réduit le diametre antéro posterieur du canal et l amincissement encore plus considérable ou la disparition de l espace sous arachnoidien (Figs 2 et 3)

Ces myélobulbographies permettent en outre de comprendre l utilité des laminectomies étendues qui peuvent aller de C1 aD2 avec ouverture en arriere du trou occipital

La myélographie gazeuse de controle (Fig 4) est effectuee trois semaines apres l intervention et montre la reconstitution de l espace sous arachnoidien identique a celui des myélographies gazeuses normales Cette liberation de la moelle bien visible rend évident le mecanisme par lequel s obtiennent les bons resultats qui suivent les operations

Stenoses du canal cervical avec aspect normal de la region du trou occipital (6 cas)

Chez ces malades le rétrécissement du canal rachidien se manifeste en dessous



Fig. 3. Même examen que fig. 2. Deflexion. L'espace sous-arachnoïdien antérieur disparaît. La moelle se plaque contre le plan disco-vertébral. Le bulbe est *coincé entre l'épais ligament* occipito-odontoïdien en avant et l'arc postérieur de l'atlas qui a fortement avancé dans le mouvement de déflexion.



Fig. 4. Même malade. Myélobulbographie six semaines après l'opération. L'espace sous-arachnoïdien est reconstitué. Amélioration rapide de la marche. Reprise du travail au 3ème mois.

apparaît plaquée contre les arcs. On observe également, quand le calibre du canal en C^5—C^6 s'abaisse à 9—10 mm (pour une moyenne normale de 13 à 15 mm), une absence totale des colonnes d'air antérieure et postérieure. Dans deux cas où il existe une courbure anormale du rachis, la moelle prend la « corde », plaquée contre l'une des parois du canal tandis que du côté opposé subsiste une colonne d'air très large, nous sommes ainsi amenés à constater que les mensurations, souvent intéressantes, ont d'autres fois une valeur assez relative.

La myélographie gazeuse met toujours en évidence une moelle à l'étroit sur toute la hauteur du canal. Le bulbe est également gêné dans un défilé cranio-cervical rétréci entre une odontoïde souvent doublée d'un ligament croisé très épais et un arc postérieur d'atlas trop court.



Fig 10 Même examen que fig 9 *Flexion* La moelle se tend p end la corde à sa pa tie supe rieure Un filet d air est cette fo s v ble ntre le cordon med ullaire et le bourrelet arth osique C5—C6



Fig 11 Myelobulbographie post operato re Lam nectom e C1—D? Reconst tution de larges espaces sous arachnoid ens anterieur et pos t eur Meme malade que dans figs 9 et 10 Amélioration de la ma che dans les premiers mois

2 Un rétrécissement du défilé cranio cervical par gros ligament croise occipito odontoidien (1 cas) Le ligament croisé épaissi fait saillie devant le bulbe et la moelle reduisant l espace sous arachnoidien (Fig 7) Le trou occipital est en outre congenitalement étroit

3 Un rétrécissement de défile cranio cervical par gros ligament postérieur (2 cas) Le gros ligament occipito atloidien posterieur forme un éperon dure ménen invisible sur les cliches simples mais évident par myélographie gazeuse surtout en déflexion il determine une saillie supprimant en partie la grande citerne (Fig 8)

Stenoses cer icales constitutionnelles compliques d arthrose

Les becs osteophytiques de l arthrose cervicale occasionnent parfois par leur importance un rétrécissement susceptible de provoquer des compressions et des traumatismes répétés de la moelle au cours des mouvements Cependant le plus souvent les mensurations nous ont montré que ce qu on appelle les



Fig 7



Fig 8



Fig 9

Fig 7 Myelobulbographie Sténose du *défilé cranio cervical* par gros ligament croisé ce dernier epaissi fait saillie devant le bulbe et la *moelle* reduisant l espace sous arachnoidien Femme de 40 ans Syndrome cérébello pyramidal

Fig 8 Myélobulbographie Sténose du défilé *cranio cervical* par gros ligament postérieur occipito atloidien L éperon dure mérien (*invisible sur le cliché* sans contraste) supprime l entonnoir Femme de 56 ans Quadriparesie évoluant depuis 4 ans

Fig 9 *Myelobulbographie* *Deflexion* Stenose du canal cervical et petite arthrose C5—C6 Disparition de l espace sous arachnoidien postérieur *Ligament* jaune refoulant la moelle contre le bourrelet arthrosique en C5—C6 *Homme de 39 ans* Paraplegie progressive

de C2 (Fig 5), tandis que la partie supérieure conserve l'aspect habituel en entonnoir, ouvert vers le haut, prolongé par la grande citerne

Sténoses du défilé cranio cervical (5 cas) Cette sténose est caractérisée par

1 Un rétrécissement d origine essentiellement osseuse (2 cas) L etroitesse du trou occipital et le raccourcissement de l arc de l atlas peuvent etre isolés ou complétés par une hypertrophie ligamentaire Ceci entraine une disparition quasi totale de l espace sous arachnoidien et de la grande citerne , un éperon ligamentaire et dure mérien supprime l entonnoir cranio cervical Il en résulte une souffrance du bulbe (Fig 6) *Il s agit d une malformation* que la radiographie standard permet de soupçonner , *normalement* le diametre o seux antéro postérieur du trou occipital mesure environ 35 mm , dans nos cas, nous avons trouvé des dimensions de l ordre de *25 a 27 mm* (dimensions réelles apres rectification de l agrandissement de 1 35 du a notre systeme de *tomographie*)

graphie gazeuse montre la disparition totale des espaces sous arachnoidiens a différents niveaux (Fig 12)

Il existe enfin des myélopathies en l absence de toute sténose quand l arthrose est tres importante Chez ces malades les dimensions des becs osteophytiques revetus d un ligament épaissi expliquent a elles seules la souffrance de la moelle (avec un canal cervical normalement large)

La mobilité de la tete est invoquee depuis longtemps comme l un des mecanismes de la souffrance medullaire dans les myelopathies arthrosiques nous avons pu mettre ce mécanisme en evidence de façon systématique et il constitue a notre avis egalement la cause principale des myelopathies dans les stenoses pures

Conclusion

Les myelites ou myélopathies chroniques forment un chapitre mal défini de la neurologie Faute de mieux on invoque souvent une sclérose en plaques et le malade reste condamné a une paraplégie progressive qui se complete souvent d une impotence des membres supérieurs

La myélobulbographie gazeuse et les résultats des interventions montrent qu un certain nombre de ces paraplégies progressives sont des maladies mecaniques susceptibles de bénéficier d un traitement chirurgical

Les sténoses constitutionnelles sans arthrose (21 cas) portent sur le défile occipito cervical et le canal cervical (10 cas), le canal cervical seul (6 cas) et le défilé cranio cervical seul (5 cas) Ces sténoses sont dues non seulement a la dimension du canal osseux visible sur la radiographie standard mais aussi a l hypertrophie des ligaments mis en évidence grace a la myélobulbographie

Les stenoses cervicales compliquées d arthrose (27 cas) ont comme cause déclenchante des signes cliniques l hypertrophie des rebords des corps vertébraux revetus de ligaments épaissis

Dans toutes ces éventualités les examens en flexion et déflexion mettent en évidence les facteurs et les mouvements traumatisants de la moelle

Lors des controles post opératoires la myélobulbographie gazeuse a permis de constater l importance de ces facteurs a l origine de la myelopathie chronique la reconstitution d un espace sous arachnoidien coincide avec la régression du syndrome clinique

RÉSUMÉ

La myélobulbographie en balayage tomographique hypocycloide avec agrandissement constant permet de voir et de mesurer les dimensions du canal rachidien des espaces sous-arachnoidiens et du cordon médullaire Elle montre parfaitement les protrusions et les épais-



Fig 12 Myélobulbographie Homme de 41 ans Paraparésie à prédominance gauche depuis un an après voyage pénible en voiture astéréognosie transitoire de la main gauche *A gauche* Canal cervical très étroit compliqué d arthrose Becs ostéophytiques postérieurs en C4—C5 C5—C6 et C6—C7 Réduction très importante du calibre du canal rachidien cervical *A droite* Contrôle postopératoire Reconstitution des espaces arachnoïdiens antérieur et *postérieur* La moelle est maintenant à une large distance des becs ostéophytiques postérieurs Amélioration postopératoire

myélopathies arthrosiques sont en réalité des sténoses constitutionnelles du canal décompensées par l'arthrose

A la période de début, l examen radiologique standard ne met en évidence que des becs ostéophytiques discrets La myélographie gazeuse montre un épaississement du ligament commun vertébral postérieur au même niveau, avec disparition de la colonne d'air antérieure

L étude dynamique fait apparaître en déflexion un empreinte de la saillie ligamentaire sur la face antérieure du cordon médullaire (Fig 9) La colonne d air réapparaît en flexion (Fig 10)

Les myélographies post opératoires montrent la formation de vastes espaces sous arachnoïdiens antérieur et postérieur qui mettent le bulbe et la moelle à distance du plan vertébral et à l abri des mouvements traumatisants (Fig 11)

D'autres fois, le rétrécissement du canal aggravé par d importants becs ostéophytiques est déjà évident sur les radiographies standards , la myélo

graphie gazeuse montre la disparition totale des espaces sous arachnoïdiens à différents niveaux (Fig 12)

Il existe enfin des myélopathies en l absence de toute sténose quand l arthrose est très importante Chez ces malades, les dimensions des becs ostéophytiques revêtus d un ligament épaissi expliquent à elles seules la souffrance de la moelle (avec un canal cervical normalement large)

La mobilité de la tête est invoquée depuis longtemps comme l un des mécanismes de la souffrance médullaire dans les myélopathies arthrosiques nous avons pu mettre ce mécanisme en évidence de façon systématique et il constitue à notre avis également la cause principale des myélopathies dans les sténoses pures

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Les myélites ou myélopathies chroniques forment un chapitre mal défini de la neurologie Faute de mieux on invoque souvent une sclérose en plaques et le malade reste condamné à une paraplégie progressive qui se complète souvent d une impotence des membres supérieurs

La myélobulbographie gazeuse et les résultats des interventions montrent qu un certain nombre de ces paraplégies progressives sont des maladies mécaniques susceptibles de bénéficier d un traitement chirurgical

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Les sténoses cervicales compliquées d arthrose (27 cas) ont comme cause déclenchante des signes cliniques l hypertrophie des rebords des corps vertébraux revêtus de ligaments épaissis

Dans toutes ces éventualités les examens en flexion et deflexion mettent en évidence les facteurs et les mouvements traumatisants de la moelle

Lors des contrôles post opératoires la myélobulbographie gazeuse a permis de constater l importance de ces facteurs à l origine de la myélopathie chronique la reconstitution d un espace sous arachnoïdien coïncide avec la régression du syndrome clinique

RÉSUMÉ

La myélobulbographie en balayage tomographique hypocycloïde avec agrandissement constant permet de voir et de mesurer les dimensions du canal rachidien des espaces sous arachnoïdiens et du cordon médullaire Elle montre parfaitement les protrusions et les épais

sissements ligamentaires arthrosiques. Mise au point pour l'étude des myélopathies inexpliquées, elle met en évidence les sténoses du canal cervical, montre les traumatismes provoqués sur la moelle par la flexion et la déflexion. Les myélobulbographies post-opératoires montrent la disparition de la sténose et des traumatismes qu'elle provoque.

SUMMARY

Tomographic myelography in hypocycloid scanning with a constant enlargement enables us to demonstrate and measure the size of the vertebral canal, the subarachnoid space and the spinal cord. It clearly shows disc protrusions and the thickening of ligaments in arthrosis. It has been perfected in order to allow the study of unexplained myelopathies and demonstrates stenosis of the cervical canal and spinal cord damage brought about by flexion and deflexion. Postoperative myelobulbographies show disappearance of the stenosis and of the damage caused by it.

ZUSAMMENFASSUNG

Die Gasmyelobulbographie mit hypocicloider Tomographie und steter Vergrösserung erlaubt den Spinalkanal, die Subarachnoidalräume, das Ruckenmark zu sehen und zu messen. Sie zeigt genau die Diskusvorwolbungen und die arthrosischen Ligamenten-Verdikkungen. Die Untersuchung der unerklarlichen Myelopathien ergibt dass man die Stenose des cervicalkanals und die daher auf der Medulla bei Flexion und deflexion verursachten Traumatismen nachweisen kann. Die postoperative Myelobulbographien zeigen Verschwinden der Stenose und der Traumatismen die sie reizt.

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FROM THE NEURORADIOLOGICAL AND PATHOLOGICAL DEPARTMENTS OF THE UNIVERSITY HOSPITAL, GRONINGEN, THE NETHERLANDS

BIOMECHANICAL ASPECTS OF SPONDYLOTIC MYELOPATHY

by

L. PENNING and P. VAN DER ZWAAG

According to BRAIN (1956), cervical spondylotic myelopathy is the most common disease of the spinal cord during and after middle age. A difficult feature of this myelopathy is its diagnosis. Roentgenographic demonstration of cervical spondylosis is no argument in favor of the diagnosis as it is common during and after middle age. In syringomyelia spondylosis may even be more severe.

In establishing diagnostic criteria a concise concept of the genesis of spondylotic myelopathy is wanted, one has to prove that the spondylosis really is the cause of the myelopathy. We agree with many authors that the only reliable diagnostic criterion is the demonstration of cord compression by means of cerebrospinal fluid manometry and myelography. In typical cases both will show a block of the cerebrospinal fluid pathways if head and neck are in the extended position, in the flexed position free flow of the cerebrospinal fluid and contrast medium is reestablished. Mere demonstration of a protruding disc by myelography is not specific for the disease (MCRAE 1956).

A brief summary of the hypotheses underlying the diagnostic phenomena may be given. Although KAPLAN & KENNEDY in 1949 found that the manometric block in extension of the cervical spine was more or less typical of

spondylotic myelopathy and is seen already in an early stage of the disease a satisfying explanation could not be given TAYLOR & BLACKWOOD (1948) showed bulging of the ligamenta flava into the spinal canal if the neck was extended

In 1953 TAYLOR suggested that the bulging ligamenta flava would contribute to the production of cervical myelopathy by compressing the cord in the extended position of the neck thus at the same time offering an explanation for the finding of KAPLAN & KENNEDY ALEXANDER et coll (1958) myelographically measured a reduction of 50 % of the sagittal diameter of the spinal canal on extension of the neck NUGENT (1959) reported similar findings STOLTMANN & BLACKWOOD (1964) observed in specimens of the extended cervical column that at the level of C 2 3 and 4 the spinal cord occupied all space available in the spinal canal

ARNOLD (1955) and MAYFIELD (1955) made a valuable contribution by suggesting that subjects with a constitutionally small cervical spinal canal would be predisposed to spondylotic myelopathy Measurements by BOYSEN (1954) had already shown that the sagittal diameter of the cervical spinal canal is subjected to remarkably wide variations the maximal diameter being nearly 2 times as large as the minimal diameter Spondylotic bars protruding discs and so on should have a far more pathologic influence on the spinal cord if it had practically no room to give way The theory of ARNOLD and MAYFIELD was supported by WOLF et coll (1956) ALEXANDER et coll (1959) NUGENT (1959) and others In the selected material of the neurosurgical clinic (in which compression of the cord was proved by myelography) we found an average diameter of the bony spinal canal (spondylotic narrowing not included) of 12 8 mm as opposed to a normal average of 17 mm with a range of 12—22 mm (BEKS & PENNING 1964)

Other factors that contribute to a crowding of the lumen of the cervical spinal canal in extension are the step formation (HADLEY 1956) of the vertebral bodies the folding of the dura mater and the thickening of the spinal cord (BREIG 1960) PENNING (1961) showed that especially in cases of vertebral retrolisthesis the spinal canal is considerably narrowed in extension by a bony pincher formed by the body of the retrolisthetic vertebra and by the lamina of its underlying neighbour In the constitutionally shallow spinal canal this pincer mechanism might be responsible for intermittent compression of the spinal cord causing a slow development of myelopathic symptoms On the other hand the pincer mechanism might be responsible for acute neurological signs in cases of forcible hyperextension as reported by FENDER (1952) and SYMONDS (1953) in intubation for anaesthesia in tonsillectomy and in tooth extraction TAYLOR & BLACKWOOD (1948) and LOGUE (1956) explained

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L. PENNING and P. VAN DER ZWAAG

According to BRAIN (1956), cervical spondylotic myelopathy is the most common disease of the spinal cord during and after middle age. A difficult feature of this myelopathy is its diagnosis. Roentgenographic demonstration of cervical spondylosis is no argument in favor of the diagnosis as it is common during and after middle age. In syringomyelia spondylosis may even be more severe.

In establishing diagnostic criteria a concise concept of the genesis of spondylotic myelopathy is wanted, one has to prove that the spondylosis really is the cause of the myelopathy. We agree with many authors that the only reliable diagnostic criterion is the demonstration of cord compression by means of cerebrospinal fluid manometry and myelography. In typical cases both will show a block of the cerebrospinal fluid pathways if head and neck are in the extended position, in the flexed position free flow of the cerebrospinal fluid and contrast medium is reestablished. Mere demonstration of a protruding disc by myelography is not specific for the disease (McRAE 1956).

A brief summary of the hypotheses underlying the diagnostic phenomena may be given. Although KAPLAN & KENNEDY in 1949 found that the manometric block in extension of the cervical spine was more or less typical of

Table 1

Sagittal diameter (in mm) of the subarachnoidal space and spinal cord measured on the myelograms of the flexed cervical spines of 20 adult cadavers at the levels C_1—C_7

C1	C2	C3	C4	C5	C6	C7	Measured ad
Subarachnoidal space							
14— 0	13—19	11—17	11—17	10—18	10—18	10—18	Spread
17	15 1/2	14	13 1/2	13	12 1/2	12 1/2	Mean value
Spinal cord							
8—12	8—12	8—11	7—10 1/2	7—10	7—10	6—9	Spread
9 1/2	9 1/2	9	9	8 1/2	8 1/2	8	Mean value

load only or even by its own weight Increasing the load to 350 g results in a negligible further lengthening of the cord This means that the cord once stretched (and this is presumably the case in the maximally flexed cervical spine) will exert a certain force on bulging discs spondylotic bars etc REID (1960) measured in cadavers the forces to lift the cord 3 mm off the anterior border of the spinal canal in the maximally flexed neck These amounted to from 400 to 1 000 g This is in fair agreement with the considerations of BREIG

Methods and material

In order to obtain further information about functional anatomic aspects of cervical spinal canal and cervical cord and their significance in the pathogenesis of spondylotic myelopathy we made cervical myelograms in 23 cadavers in flexion and extension of the cervical spine especially in lateral projection The ages of 20 adult cadavers varied from 14 to 84 years there were 10 men and 10 women who had died of non neurological diseases with the function of the spinal cord presumably intact In addition two newborns and a child of 4 years of age were examined the child had died after surgical intervention for medulloblastoma cerebelli As a contrast medium a saturated lead acetate solution was used The solution was introduced into the spinal subarachnoid space by suboccipital puncture As a rule 40—60 ml was injected The mechanism of movement of the cervical vertebrae in these cadavers appeared to be identical with the mechanism of movement during life This was controlled by the method introduced by one of us (PENNING 1960) The films were made at a target film distance of 150 cm with the film alongside the shoulder the radiological enlargment factor is estimated to be about 1 2

Results

In extension of the cervical spine the dorsal and ventral borders of the subarachnoid space of the spinal canal are folded (Fig 1) The folding of the dorsal border is due to folding of the dura mater and of the ligamenta flava This is most evident in the region of C3—7 Slight folding was noticed in four

those cases by assuming a rupture of the anterior longitudinal ligament with pathological dorsal shift of a vertebra, followed by immediate reposition.

Although mechanical factors seem to play an important role in the genesis of myelopathy, other factors may also be responsible, especially vascular factors. MAIR & DRUCKMAN (1953) investigated in some detail four cases of cord compression by a herniated disc. The distribution of the lesions in these cases appeared to be identical with the area of supply of the anterior spinal artery, except for the sparing of the anterior columns. According to these authors the lesions are caused by compression and distortion of the anterior spinal artery by the protruding disc material. LOGUE (1957) called this theory attractive because it explains the development of symptoms above the level of compression, such as spasticity of the muscle groups of the arm in a low disc lesion, at C5—6 or even C6—7. Several authors (CLARKE & ROBINSON 1956, NUGENT 1959, TAYLOR 1964, and others) have stressed the important role of vascular factors. It is felt however that mechanical compression of the cord might imply compression of its intrinsic vessels including the anterior spinal artery. Compression of the spinal rami of the vertebral arteries in the intervertebral foramina and compression and atherosclerosis of the vertebral arteries may add to the onset and progression of the disease. NUGENT (1959) suggested that 'connective tissue factors' might contribute to the development of a myelopathy, often adhesions between dura and arachnoid as well as between arachnoid and pia are found. It seems possible that these adhesions may carry collateral blood vessels and have a reparative function.

In contradiction to the theory that extension and hyperextension of the neck are the significant movements that contribute to the genesis of spondylotic myelopathy, some authors believe that flexion and hyperflexion are to be blamed. As shown by O'CONNELL (1956), the spinal canal lengthens in flexion and shortens in extension, implying changes in position and the form of the spinal cord. BREIG (1961), in his monograph concerning 'biomechanics of the central nervous system', states that the cord shows a plastic adaptation to the changes in form of the spinal canal and not a shift in axial direction as suggested by O'CONNELL (1956), nor an elastic displacement of all parts of the cord towards a certain point in the midcervical region as found by SMITH (1956). According to BREIG the cord is compressed axially in extension and drawn out in flexion. The cross sectional area increases and decreases in extension and flexion, respectively. In flexion of the neck an axial tension appears in the spinal cord. If the cord is hyperelongated, as may be the case in cervical hyperkyphosis, hyperangulation, bulging discs and spondylotic ridges, etc., neurological damage might result. BREIG demonstrated that in vitro the isolated, suspended spinal cord is extended to its maximal length by a small

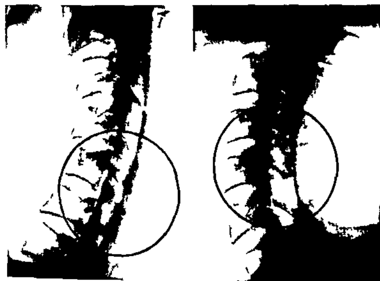


Fig 2 C vical myelograms with the neck in flexion and extens on In ex tension far less contra t agent surrounds the cord in the region C3—6

direction (Table 1) In one specimen (man 84 years) the sagittal diameter proved to be smallest at C 2 14 mm increasing caudally to 18 mm at C7

At C5 the mean sagittal diameter in flexion is 16 mm In midposition the sagittal diameter of the subarachnoid space is largest A small folding may be present due to bulging of the flaval ligaments discs etc therefore two values for the diameter must be given It ranges from 8—10 to 17—19 mm with a mean value of 12 1/2—14 mm (measurements at the level of C5)

Table 2

Sa ittal diamet r (n mm) of the bony spinal canal subarachnoidal space and spinal cord of the cervical spine in flexion udposition and extension measured on the myelograms of 20 adult cadavers at the level of C5

	Fle t			Midposit on			E tens on		
	in	ma	m n	min	max	mean	min	m x	mean
B y p n l c nal	12 1/2	0	16 1/2	12 1/2	20	1C 1/2	12 1/2	20	16 1/2
S barachno dal pac	10– 12	18	13	8 –10	17—19	12 1/2—14	8 1/2 –10 1/2	12—1	11—13
Sp n l c d	7	10 1/2	8 1/2	7 –7 1/2	11	9—9 1/4	8—8 1/2	11	9—9 1/2



Fig. 1. Cervical myelograms with the neck in flexion, midposition and extension. 65 year old male cadaver. In extension the folding of the walls of the spinal canal is clearly visible; the walls of the spinal cord are slightly undulated. In flexion dura and spinal cord are stretched. The spinal cord in flexion is smaller than in extension and follows the shortest possible route through the spinal canal.

preparations. In the two newborns and the child folding was practically absent. The folding of the ventral border must be ascribed to step formation of the vertebral bodies and folding of the dura; in elderly persons bulging of discs, spondylotic ridges and retrolisthesis contribute to the folding.

In flexion of the cervical spine the dorsal border of the spinal canal is straight, due to stretching of the flaval ligaments and of the dura. The ventral border as a rule is straight, but may be slightly undulated because of some step formation of the vertebral bodies. As bulging of discs are flattened out in flexion, no significant impression on the contrast column is visible; the same is true for retrolisthesis. In larger bulging of discs and spondylotic ridges, impressions on the ventral border of the spinal cord are noted.

As the midposition of the cervical spine varies from subject to subject a description of the normal configuration of the spinal canal cannot be given. It assumes the characteristics, though to a lesser degree, of the flexed spinal canal in the kyphotic or stretched type, and of the extended spinal canal in the lordotic type.

The sagittal diameter of the flexed spinal canal (spinal subarachnoidal space) is largest at the foramen magnum and decreases gradually in the caudal

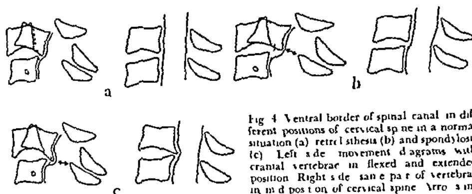


Fig 4 Ventral border of spinal canal in different positions of cervical spine in a normal situation (a) retrolisthesis (b) and spondylosis (c) Left side movement diagrams with cranial vertebrae in flexed and extended position Right side same part of vertebrae in mid position of cervical spine Arrows indicate bony pincers mechanism

pressed away from the cervical region in extension and flows in during flexion (Fig 2)

As to the position of the spinal cord in the spinal canal in different positions of the neck we find that in extension the cord is more or less clenched between the ventral and dorsal borders of the spinal canal dependent on its constitutional width The difference between the sagittal diameter of the subarachnoidal space and of the spinal cord at the level of C4—5 and C5—6 in the extended spine varies from 0—3 mm for the wider spinal canal (bony sagittal diameter at C5 more than 16 mm) the mean value is 3 5 mm for the smaller canal (bony sagittal diameter less than 17 mm) 1 7 mm

In flexion the cord always has a stretched appearance apparently following the shortest possible route through the spinal canal (Fig 3) In lordosis the cord contacts the ventral border of the spinal canal in the C5—6 or even the C4—7 region In the more cranial region the cord is free from the wall or contacts the ventral border (C2 –3 region) of the spinal canal

Discussion

Analysing the results of the myelographic examinations we note two basic phenomena that may be of significance in the understanding of the genesis of spondylotic myelopathy 1) narrowing of the subarachnoidal envelope around the spinal cord in extension of the neck and 2) stretching of the cord in flexion of the neck

As to the narrowing of the subarachnoidal space the myelograms confirm that folding of the dorsal wall of the spinal canal is a physiological phenomenon in the adult In our youngest specimens (cervical spines of a girl of 14 and a male of 33) however folding was less evident as it also was in the newborns

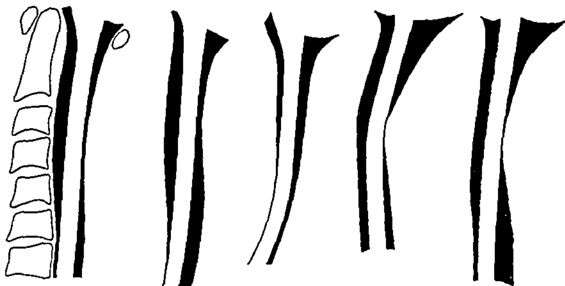


Fig. 3. Position of the spinal cord in several flexed spines (drawings after the myelogram). The cord invariably follows the shortest possible route through the spinal canal.

In extension the spinal subarachnoidal space proves to be the smallest with values of 7—10 mm to 12—15 mm and a mean value of 11—13 mm.

The spinal cord has a maximum sagittal diameter at the level of the foramen magnum and atlas and gradually decreases in the caudal direction. An indication of the intumescentia cervicalis in the sagittal plane is visible in infants and newborns only.

Measured at the level of C5 the cord has a sagittal diameter of 7—10 1/2 mm (mean value 8 1/2 mm) in flexion (Table 2). In extension the cord may show slightly undulating borders, with some variation in diameter: the mean diameter was 9—9 1/2 mm. *As a rule the cord is smallest at the levels of the bulging ligamenta flava and intervertebral discs. In midposition of the cervical spine the cord measured 7—11 mm with a mean value of 9—9 1/4 mm.* These values are in fair agreement with the values found by ELLIOT (1946) and JIROUT (1959).

Comparing the measurements of the spinal canal in flexion and extension with the measurements of the spinal cord it is evident that the cord has less surrounding subarachnoidal space in extension than in midposition and flexion, especially in the intervertebral regions. As a rule the sagittal diameter of the subarachnoidal space here is 1—2 mm smaller in extension then in flexion while the cord is 1/2—1 mm broader. Our myelograms clearly show that the contrast agent surrounding the cord in the C3—7 region is much less in extension than in flexion. We may conclude that the cerebrospinal fluid is

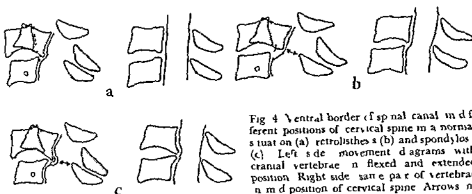


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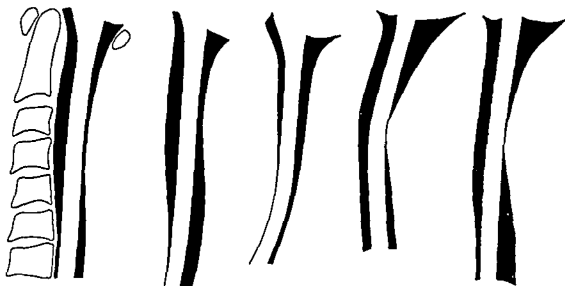


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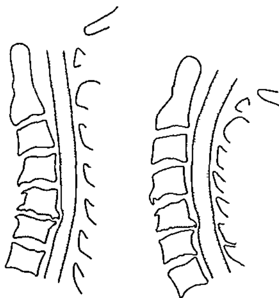


Fig 6 For legend see opposite page



Fig 5 Films of the cervical spine of a 62 year old electrotechnician with slowly progressing weakness of the right arm and both legs of 3 months duration After a forced hyperextension during maxillary sinus puncture a complete paralysis of right arm and both legs developed Left extension position retrolisthesis C3—4 and C4—5 with bony pincers of 10 mm postural manometry total block in extension normal readings in flexion pantopaque myelography stop at C3—4 in extension After laminectomy C4 and C5 and nearly complete recovery followed

and the child Perhaps a certain loss of elasticity of the flaval ligaments plays a role, as suggested by TAYLOR (1951), PAYNE & SPILLANE (1957), and others The maximal narrowing in our cases, 10 %, as compared with the situation in flexion, occurred in a male specimen, aged 84

Fig 6 Cervical spine of a 54 year old woman with weakness and ataxia of lower limbs of three weeks duration Right extension position retrolisthesis C5—6 with bony pincer of 11 mm diameter postural manometry no stop in extension pantopaque myelography no stop Diagnosis compression of cord in extension is improbable Left flexion position important degree of kyphosis the spondylotic ridges C4—6 protrude into the spinal canal Spine fusion in moderate extension was performed (C3—7) with considerable improvement Drawings show the two ways in which the spinal cord could be affected by spondylosis and retrolisthesis C5—6 the possibility of cord compression in extension was rejected because of normal findings in postural manometry and myelography

such protrusions may obstruct the blood flow in the spinal arteries in the maximally flexed spine A protrusion spondylotic bar etc must however reach considerable dimensions to have a *height of 3 mm on the ventral border* of the flexed spine As pointed out before and shown in Fig 4 protrusions have a tendency to flatten if the spine is flexed

From a diagnostic point of view the pathogenetic value of a certain degree of spondylosis and a certain degree of hyper kyphosis of the flexed cervical spine is difficult to evaluate Firstly in children and adults the cervical spine may assume an important kyphotic curvature in flexion apparently without ill effects on the cord Secondly, myelographic *demonstration of protrusions* i difficult in the flexed spine (at least with pantopaque, gasmyelography offers distinct advantages) moreover a reliable criterion in assessing the pathogenetic quality of the protrusion is lacking The test of KAPLAN & KENNEDY in this context is useless as the cord and subarachnoidal space are not compressed but impressed

We tend to support the hypothesis of REID and of BREIG that stretching of the cord may play a role in the production of chronic myelopathy, but in the meantime its usefulness, at least clinically is doubtful In Fig 6 the case of a patient is shown where we considered the diagnosis of impression of the cord in flexion and adequate therapeutic measures were taken

Our studies give no support to the wellknown theory of KAHN (1947) postulating that free movement of the spinal cord posteriorly away from a protruding disc is prevented by the tethering function of the ligamenta denticulata resulting m chanically in an area of primary stress in the vicinity of the attachments of the ligaments to the meridian of the cord As the cord in flexed spine follows the shortest possible route through the spinal canal the tethering function of the dentate ligaments in an antero posterior direction cannot be of much importance According to KEY & RETZIUS (1875) the dentate ligaments become shorter in the cranial direction As a consequence the spinal cord in the C2/3 region should lie ventrally in the spinal canal the myelograms however prove the contrary Moreover the relative free antero posterior mobility of the cord within the spinal canal was shown by JIROUT (1959) and recently by STOLTMANN & BLACKWOOD (1964)

SUMMARY

The mechanical theories explaining the genesis of spondylotic myelopathy offer two different viewpoints compression of the spinal cord in extension and impression of the cord in flexion On the bas s of myelograph c experiments in cadavers we conclude that both theories may

The folding of the ventral wall of the spinal canal is due not only to slackening of the dura but also to the normal backward gliding movement of the vertebral bodies in relation to their underlying neighbours. As a consquence, disc protrusions on the ventral border of the spinal canal will cause an increased *narrowing effect on the spinal canal in* extension, whereas their effect in flexion is decreased (Fig. 4). Disc protrusions are most evident, myelographically, in extension. Perhaps this explains why the surgeon is sometimes disappointed at the operation, because as a rule the spine then is in the flexed position.

The myelograms confirm that, if compression of the cord occurs, it occurs at first in extension. The need for 'postural' manometry and 'postural' myelography should be emphasized. Although the myelograms show that in extension the subarachnoidal space in the midcervical region may be practically obliterated, pathological manometrical readings in extension in normal subjects were not noted by KAPLAN & KENNEDY. As an explanation the small bore of the lumbar puncture needle is held responsible, if only more cerebrospinal fluid could pass through the cervical region than through the needle, the test would give normal results. Good correlation between the results of postural manometry and myelography were reported by BRAHAM & HERZBERGER (1956), CLARKE & ROBINSON (1956), TENG (1960) and others. It proves that the test of KAPLAN & KENNEDY is valuable in differentiating spondylotic myelopathy from other myelopathies. A clinical example is given in Fig. 5.

In 2 of the 12 cases of KAPLAN & KENNEDY with pathological manometric readings a block in flexion was found, with normal results in extension. The cases were not verified surgically. An explanation could not be given. Our myelographic investigations too do not contribute to a better understanding. We can only refer to the case of CLARKE & LITTLE, where intermittent cord compression at the level of C2/3 occurred on flexion of the spine. In our opinion, a similar occurrence is only possible in anterolisthesis of a cervical vertebra, as opposed to retrolisthesis where compression takes place in extension (PENNING 1961, 1964).

In the flexed cervical spine the spinal cord invariably follows the shortest possible route through the spinal canal. This proves that a certain amount of stretching is present, completely in accordance with the observations of REID (1960) and BREIG (1960). Pressure of the cord against the ventral border of that spinal canal is mainly to be expected in the C5—6 or C6—7 region, the extent and force being dependent on the degree of kyphosis of the cervical spine in flexion. *After converting the given values of* REID it becomes evident, that the pressure of the cord against a spondylotic bar of 3 mm height on the ventral border of the spinal canal averages about 1 000 mm Hg. This exceeds the blood pressure of the spinal arteries many times. It is obvious then that

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be valid though only compression in extension can be proven in the clinical case Before assuming impression of the cord in flexion compression in extension should be ruled out by postural manometry and myelography

ZUSAMMENFASSUNG

Die mechanischen Theorien zur Erklärung der Genese der spondylotischen Myelopathie bieten zwei verschiedene Ansichten Kompression des Ruckenmarks in Extension und Kompression in Flexion Auf Grund von myelographischen Versuchen an der Leiche mogen beide Theorien ihre Gultigkeit haben obwohl nur die Kompression in Extension klinisch gepruft werden kann Bevor man sich fur die Impression des Ruckenmarks in Flexion entscheidet sollte die Kompression in Extension mittels Manometrie und Myelographie ausgeschlossen werden

RÉSUMÉ

Les théories mecaniques expliquant la pathogénie de la myélopathie par arthrose vertébrale comportent deux hypothèses différentes compression de la moelle épinière en extension et impression de la moelle en flexion L expérimentation myélographieque sur le cadavre nous fait conclure que les deux théories peuvent être vraies bien qu on ne puisse prouver dans les cas cliniques que la compression en extension Avant d admettre l impression de la moelle en flexion on devrait éliminer par manométrie posturale et myélographie la possibilité de la compression en extension

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DOUBLE CONTRAST MYELOGRAPHY

by

TOMAZ REZENDE

Myelography has been much discussed, both as regards the method of the examination and the best contrast media, since it was introduced by DANDY in 1919 The author favours lumbar puncture with air or gas as a negative contrast medium The entire subarachnoid space may thus be studied and the examination repeated as often as desired without fear of complications such as arachnoiditis and granulomata

We have devised a method, based on physical laws, of performing myelography with two contrast media in cases of complete or partial block of the spinal canal The upper and lower poles of the lesion, preferably with the aid of tomography, may thus be demonstrated in a single film

The technical details may be varied The examination may commence with lumbar pneumomyelography with the patient seated (7, 8), followed by the injection of a positive contrast medium by the suboccipital route Alternatively the suboccipital injection of gas or air (4, 5, 6, 7, 8) with the patient in the Trendelenburg position may be followed by the lumbar injection of a positive contrast medium (Pantopaque (1, 9) Myodil, Ethiodan) The author has employed the latter method in 5 cases

The main advantages of the method appear to be 1) The positive contrast

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Awarded the Austregésilo Prize in 1964 by the National Academy of Medicine Rio de Janeiro Brasil



Fig 1 Double contrast myelography before tomography Positive contrast injected in the lumbar region Almost total block at level of Th 5 Air introduced by suboccipital route in the Trendelenburg position The air column delineates the spinal cord and reveals obstructions at level of Th 4



Fig 2 The delineation of the spinal cord and the tumour are improved by tomography

medium is used only once and in a small quantity 2) precision is obtained in determining the limits of the block in the spinal canal since the exact size of the lesion will be demonstrated in a single film 3) despite tomography the method is practical and inexpensive a median section in profile sometimes suffices 4) the Trendelenburg position may be avoided at least for part of the time in old people or in those with cardiac or pulmonary disease (3, 4 5)

As disadvantages it may be mentioned that suboccipital puncture is necessary and this by itself represents a dangerous procedure The second obvious disadvantage is the use of positive contrast media

Case report

A white female aged 59 who at the end of 1962 had weakness while walking and had fallen to the ground several times The condition progressively deteriorated There was no sphincter involvement She was admitted in March 1963 with crural paraplegia

Physical examination suggested spinal cord compression characterized by spastic paraplegia with possible sensory loss below Th 8 Roentgen examination revealed slight osteoarthritis in the thoracic spine Double contrast myelography disclosed a juxta medullary expansive lesion about 2 cm in size posteriorly at the level of Th 5 At operation (laminectomy) a

spherical tumour was found lying posterolaterally and displacing the spinal cord anteriorly and slightly to the right A histologic examination of the specimen proved it to be a meningioma

Postoperative course Uneventful recovery The patient started to walk again about a month later

SUMMARY

The author describes a technique for myelography with double contrast media (negative and positive) performed with or without tomography

ZUSAMMENFASSUNG

Der Verfasser beschreibt die Durchfuhrung der Myelographie mit doppoltem (negativem und positivem) Kontrastmedium mit oder ohne Tomographie

RESUME

L auteur décrit une technique de mielographie avec double contrast (negatif et positif) sans ou avec tomographie

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LE FOURREAU DURAL LOMBO SACRE

Etude radio anatomique

par

G SALAMON R LOUIS et G GUERINEL

Le fourreau dural lombo sacre represente l enveloppe dure merienne des racines de la queue de cheval Il s etend du cone terminal jusqu aux premieres vertebres sacrées

D apres les auteurs classiques la moelle se termine a la hauteur de L2 alors que le fourreau dural se termine en S2 En fait de nombreuses variations peuvent intéresser ce segment de la dure mere Les travaux anatomiques qui concernent cette region sont deja fort anciens (KEY & RETZIUS 1875 CHIPAULT 1885)

Trois elements ont contribue a mieux faire connaitre ce segment des formations intra rachidiennes D une part la possibilite d y injecter des substances iodees huileuses ou hydro solubles D autre part la connaissance de hernies discales lombaires et enfin la possibilite d un traitment chirurgical

L importance de cette pathologie radiculaire qu un examen assez simple permet de soupçonner a donc mis l accent sur un segment du systeme nerveux central peu étudie jusque la

On dispose a l heure actuelle de confrontations anatomiques (dissections corrosions de pieces plastiques coupes de rachis congeles) et radiologiques

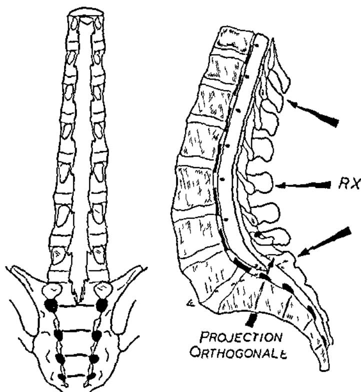


Fig. 1. Schéma de face et de profil du cul de sac dural lombo-sacré. On retiendra de face l'aspect festonné du cul de sac, chaque émergence radiculaire déterminant une véritable évagination de la dure-mère. Sur le cliché de profil on conçoit la discordance qui peut exister entre le système de référence anatomique, référence orthogonale par rapport au rachis et la référence radiologique.

(examens myélographiques par myélographie gazeuse, lipiodol ou méthiodal) qui permettent d'avoir une idée très précise sur la topographie du cul de sac dural et des racines.

Les examens radiologiques les plus précis sont constitués par des myélographies aux hydro-solubles. En effet, leur résorption rapide permet d'injecter des quantités assez importantes pour obtenir un moule satisfaisant de l'ensemble du cul de sac. La faible opacité de ces produits donne une image satisfaisante des racines et de leur émergence.

Nous avons sélectionné 150 myélographies normales, et pour chacune d'elles, nous avons étudié le niveau de terminaison, la forme du cul de sac, le niveau d'émergence des racines et leurs types morphologiques. Les données anatomiques nous ont été fournies soit par des dissections, soit par des moulages aux résines plastiques avec corrosion des pièces, soit, enfin par injection du



Fig 2 Myelographie du méthiodal Aspect normal Incidences de face 3/4 et profil On retrouve sur ces clichés l aspect festonné du cul-de-sac correspondant aux emergences radiculaires L incidence de profil montre les saillies au niveau des espaces intervertebraux provoquees par le disque et son surtout ligamentaires

cul de sac et radiographies des coupes horizontales de 1 centimetre d epaisseur permettant ainsi d avoir une vue axiale du fourreau

Nous avons utilise les renseignements de dissections du cul de sac chez 75 sujets (Figs 3 6 7 8 9 15)

Nous avons ainsi pu preciser le mode de terminaison la forme du cul de sac et l emergence des racines et comparer ces resultats a ceux des examens myelographiques Apres ouverture du cul de sac nous avons pu observer la disposition intra durale des racines et leur mobilite aux mouvements de flexion ou d extension du rachis (Fig 9)

Dans d autres cas l injection d une resine plastique melangee a du sulfate de baryum a permis d obtenir par corrosion de veritables moules radiopaques du cul de sac (Figs 4 et 5)

Enfin sur des rachis entiers les espaces sous arachnoidiens ont ete injectes de minium Les pieces ainsi congelees ont ete coupees en tranches d epaisseur

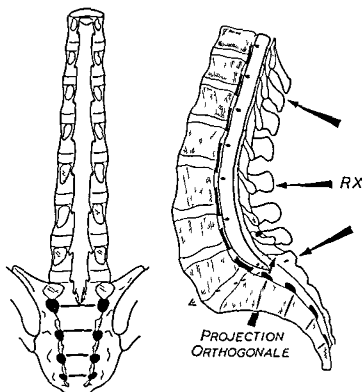


Fig. 1. Schema de face et de profil du cul de sac dural lombo sacré. On retiendra de face l'aspect festonné du cul de sac, chaque emergence radiculaire determinant une veritable evagination de la dure mere. Sur le cliché de profil on conçoit la discordance qui peut exister entre le systeme de reference anatomique, reference orthogonale par rapport au rachis et la référence radiologique.

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Fig 4 Radiog aph e d un moulage de cul de sac Methode de corrosion Les sillons plus cla rs repré entent ici l empreinte des racines que l on peut suivre jusqu à leur sortie du fourreau du al

et sa hauteur A ce propos il faut signaler quelques divergences entre les donnees anatomiques et radiologiques (Fig 17)

Les constatations anatomiques se réfèrent a des projections orthogonales, c est a dire perpendiculaires a l axe du canal rachidien le sujet etant en position indifferente Par contre la projection radiographique est une projection conique divergente ne te ant aucun compte de l axe rachidien si bien qu un cul de sac dural se terminant orthogonalement au niveau du disque S1—S2 se projette radiographiquement de face par la forte obliquite du sacrum au niveau du disque sus jacent L5—S1

Dimension du fourreau dural La hauteur moyenne du cul de sac mesuree sur des moulages plastiques nous a paru etre comprise entre 13 et 18 centimetres (Fig 5)

De meme l immersion de ces moules nous a permis d en determiner le volume moyen (non compris le volume des racines detruites par la corrosion) Ce volume est compris entre 15 et 23 cm³

Morphologie du fourreau dural Jusqu à la hauteur de L3—L4 le cul de sac presente une forme triangulaire correspondant aux parois du canal ostéo fibreux qui l entoure (Figs 6 7 8)

Au dessous de L 4 le cul de sac varie de calibre de façon importante Certains



Fig 3 Aspects du cul de sac dural sur une dissection anatomique L'émergence des racines n'a jamais lieu à la face postérieure du disque Lorsque les racines croisent la partie postérieure du disque inter vertébral elles sont déja assez éloignées du fourreau dural

de 1 centimetre, perpendiculairement à l'axe du rachis, ces coupes passant soit par les corps vertebraux, soit par les disques permettent d'étudier les rapports anterieurs et lateraux du fourreau dural, ainsi que la disposition dans un plan horizontal des racines de la queue de cheval (Figs 6, 7, 8)

Les donnees anatomo radiologiques permettent de fixer sa situation sa forme, ses mesures et ses rapports

Situation du fourreau dural Le fourreau dural lombo sacre s'etend de l'interligne D12—L1 jusqu'a la région comprise entre S1—S2 En haut le fourreau dural fait suite a l'enveloppe dure merienne de la moelle et du cone terminal En bas, le fourreau se termine soit au niveau de l'interligne S1—S2, soit au niveau de l'interligne S2—S3 (Figs 1, 2, 18) Plus exceptionnellement, le fourreau dural se termine au milieu de S2, ou à la hauteur du disque S3—S4 Il est fréquent de rencontrer une terminaison du cul de sac d'autant plus basse que le cone terminal est lui meme plus bas situé

Par contre, il ne semble exister aucune relation entre la forme du cul de sac



Fig. 4 Radiographie d un moulage de cul-de sac Methode de corrosion Les sillons plus clairs representent ici l empreinte des racines que l on peut suivre jusqu a leur sortie du fourreau dural

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Fig. 5. Moulages de cul de sac duraux. Pièces plastiques obtenues par corrosion. On remarquera les différences de calibre de terminaison et d'émergence radiculaires.

d'entre eux, très larges, gardent à ce niveau la même configuration qu'à l'étage sus-jacent : remplissent le canal lombo-sacré et prennent contact avec toutes ses parois, alors que d'autres, plus étroits, deviennent cylindriques et s'éloignent très nettement de la paroi postérieure de L5 et de l'interligne lombo-sacré (Fig. 8). On conçoit que dans ces cas, le fourreau étant étroit, effilé, l'examen myélographique puisse rester négatif, même s'il existe une volumineuse hernie L5—S1 (LINDBLOM 1950).

Outre ces variations de hauteur correspondant à la terminaison du cul de sac, il existe nombreuses variations de formes bien étudiées par ARNELL (1948). Elles ont été schématisées sur la Fig. 17.

Le fourreau dural ainsi disposé présente un aspect festonné en regard des pédicules, en "dents de scie". Cet aspect est déterminé par l'émergence de racines rachidiennes qui soulèvent à ce niveau la dure mère, déterminant ainsi une véritable fossette intra-durale. Nous les étudierons avec les racines de la queue de cheval (Figs. 1, 15, 16).

Les racines de la queue de cheval

A l'intérieur du fourreau dural se trouvent disposées près de 15 racines sensitivo-motrices correspondant aux territoires lombaires, sacrés et coccygiens (y compris le filum terminale).

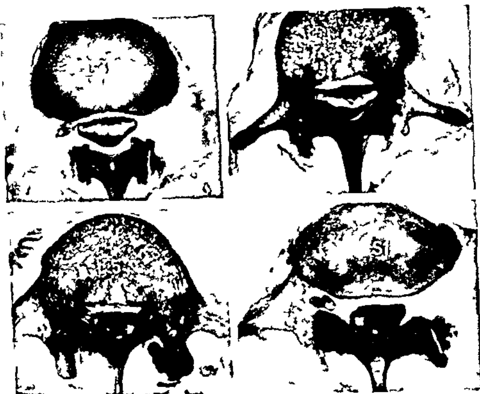


Fig 6 Coupes horizontales de rachis. Pièces congelees avec injection du cul-de sac dural au plomb Ces coupes passent par L3—L4—L5—S1 Elles interessent les corps vertebraux En L4 et L5 l emergence de racines correspondantes determine de veritables evaginations latérales

Les racines comme le montrent les coupes horizontales du rachis (Figs 6 7 8) sont disposees en arc de cercle ouvert en avant de telle sorte qu aux extremites de l arc se trouvent les deux racines droite et gauche qui vont traverser le fourreau en s éloignant vers le sommet posterieur de l arc on trouve les racines les plus inférieures de part et d autre du filum

A chaque etage lombaire ou sacre deux racines sensitive et motrice de chaque cote abandonnent le fourreau dural et vont ainsi constituer le nerf rachidien L origine de ces racines et leur traversee duremerienne representent des éléments anatomiques d une certaine fixite Il faut egalement signaler la mobilité de ces racines tres relachees en hyper extension et tendues rectilignes en hyper flexion (Fig 9) L émergence durale de ces racines determine on l a vu une veritable fossette Chaque racine motrice ou sensitive perfore la dure mere par un orifice distinct les deux orifices étant separes par un septum (Fig 15)

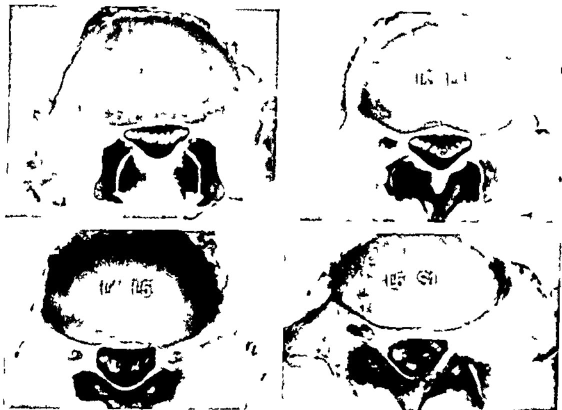


Fig 7 Coupes horizontales du rachis Pièces congelées avec injection du cul de sac dural au plomb *Ces coupes passent par les disques inter vertébraux L2—L3 L3—L4 L4—L5 et L5—S1 Ici* le cul de sac a une forme régulière triangulaire les racines à l intérieur du fourreau sont disposées en arc de cercles Au niveau des trous de conjugaison on aperçoit en L3—L4 et L4—L5 les racines émergentes

D'autre part, l évagination de la dure mère détermine au bord inférieur de celle ci un véritable repli falciforme que l on voit au cours de dissections et qui est nettement visible sur les myelogrammes

A la partie inférieure et supérieure de ces racines, il existe deux fossettes l'une supérieure, l'autre inférieure Ces deux fossettes sont déterminées par la racine elle même qui vient isoler deux étages sous arachnoïdiens à l'intérieur de l'évagination durale due a la traversée des racines

Alors que les racines sous jacentes sont disposées verticalement, les racines qui vont sortir du fourreau ont une courbure arciforme comme si elles étaient tendues sur la poulie que représentent a ce niveau les pédicules Ce changement de direction (Figs 10 11, 12, 13) est important à considérer, car il est souvent affecté par une hernie discale

L'espace arachnoïdien sus radiculaire constitue une fossette, la fossette sus radiculaire, dont la forme est très variable Elle se trouve comprise entre

Fig 8 Coupes horizontales du rachi Pieces cong lees et injectees au m nium Les 2 coupes de d oite nte essent un ul-de sac t es etro t Les 2 coupes de gauche interessent un cul de sac tres la ge On voit l importante d fference qui existe a l etage L5—S1 entre les deux varietes le cul de sac On conço t qu une hern e i nportante ne donne aucun signe myelograph que dans le prem er cas

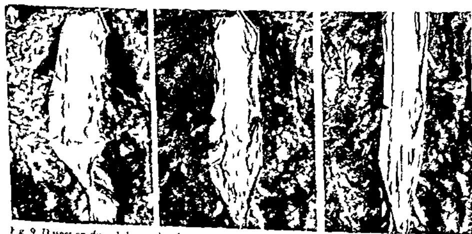


Fig 9 Dissect on du ul-de sac du l ap es ouve ture du four eau Les ra ines s nt photographi es d b d en exten on pu n posit n ind ffe ente et enfin en flex on La flexion du rachis tend n b ment les rac nes omme les ordes d un arc



Fig. 10. Émergence radiculaire avec fossettes sus et sous radiculaires longues. Cet aspect peut se voir au niveau de S1.



Fig. 11. Émergence radiculaire avec fossettes radiculaires à peine ébauchées.

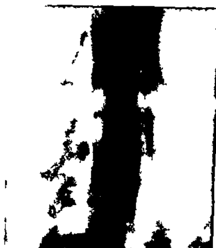


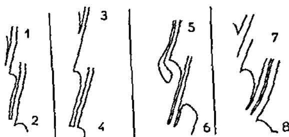
Fig. 12. Émergence radiculaire avec aspect kystique d'un recessus.



Fig. 13. Émergence radiculaire d'aspect habituel avec fossette sous radiculaire triangulaire en console.

les racines prêtes à sortir, et la paroi durale susjacente à sa sortie. Certaines sont triangulaires, d'autres quadrangulaires. De nombreuses variations peuvent se voir schématisées sur la Fig. 14.

La fossette sous radiculaire, par contre, présente une morphologie plus constante. Elle est pratiquement toujours de forme triangulaire, sa base étant arciforme, à concavité inférieure. Sa constitution nous explique sa forme triangulaire, elle est limitée, en effet, par trois portions : en haut, la racine



F g 14 Schema des pr ncipaux types d emergence rad culaire



F g 15 Dissection du cul-de sac dural Vue interne d une fossette ad cu la e On distingue les 2 racines et le schema repr sente leurs or fices de sortie d st ncts

qui traverse la dure mere en bas la faux de l orifice de traversee en dedans, la racine sous jacente

Cet aspect existe de façon constante a tous les niveaux mais interesse surtout les racines de L2 a S1 ou S2 suivant le niveau plus ou moins bas de terminaison du sac dural Cette fossette sousradiculaire plus large que la precedente est tres souvent comprimee et disparait s il existe une hernie discale meme de petit volume La compression ou la disparition de cette fossette donne l impres sion d un elargi sement apparent de la racine au moment de sa traversee Ce signe decrit comme signe du tromblon était attribue a un oedeme radicu laire à ce niveau Cet oedeme localise est d autant moins probable qu il est limité et qu il est d ailleurs exceptionnellement retrouve lors d interventions neuro chirurgicales En fait cet elargissement apparent de la racine est du simplement à la compression directe de la hernie qui vient à ce niveau

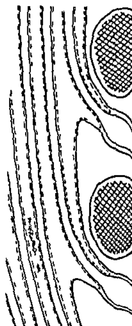


Fig 16 Coupe vertico frontale du cul de sac niveau des emergences radiculaires

comprimer la dure mere, effaçant la fossette sous radiculaire L' *bsence d* cette fossette permet d'affirmer avec quasi certitude, l existence d une *protru*sion discale

Les deux *fossettes* sont d'une longueur variable En particulier, en regar de S1, elles peuvent etre assez longues, et cela, d autant plus que le *cul de sa* dural est plus etroit (Fig 10) Il est assez rare, par contre, qu elles *soient* pe marquees, le cul de sac ayant alors une forme *cylindrique* (Fig 11)

Le niveau de la fossette sous radiculaire donne avec precision le niveau d emergence durale des racines Au dela de cette limite, il existe souvent un g ine arachnoidienne, mais, elle ne s injecte pratiquement *jamais par l emplo* de *produits iodes* Par contre, l injection de pieces anatomiques au minium nous a permis souvent d opacifier la gaine arachnoidienne sur une longueur un peu plus grande que sur les myelographies aux produits iodes hydrosolubles

Les fossettes sus et sous radiculaires communiquent largement avec les espaces sous arachnoidiens du sac dural, et il serait faux de pretendre que chaque racine possede une gaine arachnoidienne qui lui soit *propre tout le long de* trajet intra dural, et, que le liquide cephalo rachidien qui l occupe, ne puisse communiquer aisement autour des racines voisines

On conçoit ainsi que, quelle que soit la methode d examen myelographique que l'on *emploie*, l'opacification du cul de sac et des fossettes radiculaires soit toujours satisfaisante



F g 17 Princ p ux types de te n naison de cul de sac dural

Il nous semble aussi pour cette raison assez demesure de pratiquer deux examens myelographiques droit et gauche alors qu au cours d un meme examen il suffit de retourner le malade pour obtenir une opacification tres satisfaisante des recessus radiculaires des deux cotes

Les donnees de dissection et l analyse de myelographies montrent qu il existe un niveau moyen d emergence assez constant pour chaque racine (Fig 18) Les racines nais ent d autant plus bas que la terminaison du cul de sac est plus basse

On peut admettre lorsque le cul de sac s arrete au niveau du disque S1—S2

1 Que la racine L2 quitte le cul de sac a mi hauteur de la deuxieme lombaire

2 Que la 3eme racine lombaire quitte le cul de sac au 1/3 superieur environ de la troisieme piece lombaire

3 Que L4 quitte le cul de sac au 1/4 superieur de la quatrieme piece lombaire

4 Quant a L5 elle quitte le cul de sac au 1/5 superieur de la cinquieme vertebre lombaire alors que S1 le quitte *soit* au niveau soit quelques millimetres au dessus de l interligne lombo sacre

Quand le cul de sac se termine plus bas a la hauteur du disque S2—S3 l émergence des racines se fait plus bas que pour le cas precedent ainsi L3 nait au milieu du corps de L3 L4 vers le 1/3 superieur de L4 et L5 au niveau du 1/4 superieur de L5 tandis que S1 nait a la hauteur du disque L5—S1 soit a quelques millimetres au dessous

Enfin certaines anomalies de naissance se voient soit sur des dissections de pieces anatomiques soit sur des myelographies (CANNON HUNTER & PICAZA 1962)

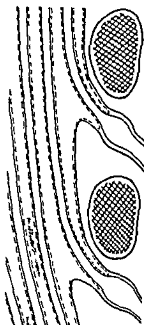


Fig 16 Coupe vertico frontale du cul de sac niveau des emergences radiculaires

comprimer la dure mere, effaçant la fossette sous radiculaire L absence de cette fossette permet d affirmer avec quasi certitude, l'existence d une protrusion discale

Les deux fossettes sont d une longueur variable En particulier en regard de S1, elles peuvent etre assez longues, et cela, d autant plus que le cul de sac dural est plus etroit (Fig 10) Il est assez rare, par contre, qu elles soient peu marquées, le cul de sac ayant alors une forme cylindrique (Fig 11)

Le niveau de la fossette sous radiculaire donne avec precision le niveau d'emergence durale des racines Au dela de cette limite, il existe souvent une gaine arachnoidienne, mais, elle ne s injecte pratiquement jamais par l emploi de produits iodes Par contre, l injection de pieces anatomiques au minium nous a permis souvent d opacifier la gaine arachnoidienne sur une longueur un peu plus grande que sur les myelographies aux produits iodes hydro solubles

Les fossettes sus et sous radiculaires communiquent largement avec les espaces sous arachnoidiens du sac dural, et il serait faux de pretendre que chaque racine possede une gaine arachnoidienne qui lui soit propre tout le long de trajet intra dural, et, que le liquide céphalo rachidien qui l occupe, ne puisse communiquer aisement autour des racines voisines

On conçoit ainsi que, quelle que soit la methode d examen myelographique que l on emploie, l opacification du cul de sac et des fossettes radiculaires soit toujours satisfaisante

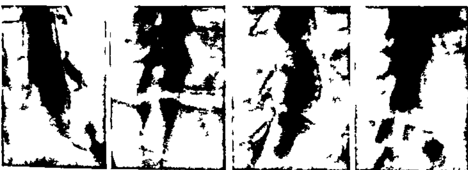


Fig 17 Pr nc paux types de termina on de cul de sac dural

Il nous semble aussi pour cette raison assez demesure de pratiquer deux examens myelographiques droit et gauche alors qu au cours d un meme examen il suffit de retourner le malade pour obtenir une opacification tres satisfaisante des recessus radiculaires des deux cotes

Les donnees de dissection et l analyse de myelographies montrent qu il existe un niveau moyen d emergence assez constant pour chaque racine (Fig 18) Les racines naissent d autant plus bas que la terminaison du cul de sac est plus basse

On peut admettre lorsque le cul de sac s arrete au niveau du disque S1—S2

1 Que la racine L2 quitte le cul de sac a mi hauteur de la deuxieme lombaire

2 Que la 3eme racine lombaire quitte le cul de sac au 1/3 superieur environ de la troisieme piece lombaire

3 Que L4 quitte le cul de sac au 1/4 superieur de la quatrieme piece lombaire

4 Quant a L5 elle quitte le cul de sac au 1/5 superieur de la cinquieme vertebre lombaire alors que S1 le quitte soit au niveau soit quelques millimetres au dessus de l interligne lombo sacre

Quand le cul de sac se termine plus bas a la hauteur du disque S2—S3 l emergence des racines se fait plus bas que pour le cas precedent ainsi L3 nait au milieu du corps de L3 L4 vers le 1/3 superieur de L4 et L5 au niveau du 1 4 supérieur de L5 tandis que S1 nait a la hauteur du disque L5—S1 soit à quelques millimetres au dessous

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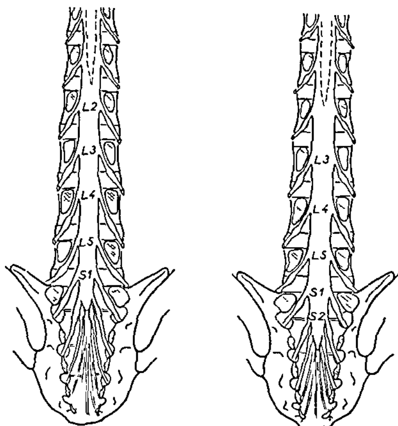


Fig. 18. Schéma des émergences radiculaires correspondant aux types les plus fréquemment rencontrés. Type S1 avec terminaison du cul de sac en S1—S2 ou terminaison en S2—S3 (87   des cas).

Discussion

Anatomie. La projection du cul de sac et des émergences radiculaires varie quelquefois avec celle que l'on observe sur les myélographies ou lors d'interventions chirurgicales. Dans le premier cas, il s'agit de références de projections différentes. Dans le second, la position opératoire du malade modifie quelque peu les rapports anatomiques, l'hyperflexion attirant de quelques millimètres vers la tête les racines sous-jacentes à L4.

La forme du cul de sac examiné en coupes est triangulaire sauf au niveau de la terminaison, variable sur le plan morphologique comme en hauteur (S1—S2).

Le cul de sac s'éloigne d'autant plus de la face postérieure des corps vertébraux que l'étage considéré est plus bas. Les racines sont disposées à l'intérieur du cul de sac, en arc de cercle.

Au niveau de leur émergence, les racines déterminent la formation de deux

recessus sus et sous radiculaires seul ce dernier est *constant dans sa forme* Le niveau d émergence radiculaire par rapport aux corps vertébraux est egalement assez constant

Radiologie On ne peut admettre qu il existe de gaines sous arachnoidiennes propre a chaque racine dans leur trajet intra dural Les racines sont toutes a l interieur du fourreau dural et entourees de liquide cephalo rachidien

L existence des gaines *radiculaires est une* fausse impression optique creee par la myelographie le produit de contraste iode venant se deposer entre chaque racine

Les myelographies montrent que le fourreau dural presente une certaine fixite jusqu en L3—L4 De nombreuses variations sont observees a partir de L5 ce qui concorde nettement avec les *donnees anatomiques*

Les fossettes sus et sous radiculaires sont determinees par les emergences radiculaires

La fossette sous radiculaire est souvent comprimée au cours de hernies discales ce qui explique le signe de tromblon beaucoup plus constamment que l oedeme radiculaire Ce signe est certainement un *signe de compression* directe par la hernie

La formation anatomique du cul de sac et des racines explique qu une excellente myelographie puisse etre obtenue quelle que soit la methode employee la meilleure etant certainement la plus rapide et celle qui donne les images dont la definition est la meilleure

Les cliches les plus importants sont ceux obtenus en oblique Il peut etre interessant pour degager ces divers recessus radiculaires de pratiquer quatre a cinq cliches sous des obliquites differentes pour obtenir ainsi un veritable balayage de cette region

RÉSUMÉ

Les auteurs ont étudié par diverses méthodes anatomiques et radio-anatomiques la situation par rappo t aux vertebres du cul-de sac dural lombo-sacré et de l emergence des racines hors du *fourreau dural* Ils expliquent pour quelles raisons les résultats de cette étude peuvent etre en désaccord avec les constatations myélographiques ou per opératoires Ils ont aussi étud é la forme du cul-de sac dural et la disposition des racines Il n y a pas une gaine arachnoi d enne *intra-durale distincte* pour chaque racine mais *seulement une fossette sus* et une fossette sous-radicula re Le signe radiculographique du tromblon semble du le plus souvent à la compress on de la fossette sous-radiculaire par la hernie discale plutot qu à l oedème adiculaire

SUMMARY

Using various anatomical and radiological methods the authors studied the dural sheaths and the emergence of the lumbo sacral roots They explain why the results of this study may disagree with the myelographic or operative findings The shape of the dural sheath and the disposition of the roots was also studied Each root does not have a distinct intradural arachnoidal sheath but on leaving the sheath produces an evagination of the dura forming two fossae one above and one below the root The sudden pain from the nerve roots would usually seem to be due to compression of the fossa below the root by the herniated disc, rather than to inflammation of the root

ZUSAMMENFASSUNG

Mit Hilfe verschiedener anatomischen und rontgenologischen Methoden wurden die Durascheiden und die Austrittsstellen der Lumbo sakralen Nervenwurzeln studiert Diese Studien machen es klar warum der Tatbestand nicht immer mit den myelographischen und operativen Befunden ubereinzustimmen scheint Die Form der Duralscheide und die Anordnung der Nervenwurzeln wurde erneut studiert Jede einzelne Nervenwurzel hat nicht notwendigerweise ihre eigene intradurale Arachnoidscheide aber sie hat an ihrer Austrittsstelle eine Ausstulpung der Dura die zwei Gruben aufzeigt eine oberhalb und eine unterhalb der Wurzel Der plotzliche Schmerz der von den Nervenwurzeln ausgeht scheint durch Kompression der unteren Grube durch Diskusprolaps hervorgerufen zu werden und nicht durch Entzundung an der Wurzel

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THE SPINAL ARTERIES

by

MANNIE M SCHECHTER and LAWRENCE H ZINGESSER

Neuroradiology is a relatively young subspecialty of radiology The growth of this subspecialty as well as the growth of the broader domain of radiology is due *in part to the great technical achievements being made in our time* Another part of our body of knowledge, however, comes out of reassessment *of material that has been with us for a relatively long period of time* Thus neglected aspects of radiologic anatomy take on a new meaning when our attention is drawn to the anatomy in question, and finally pathologic anatomy is recognized radiographically where it was passed over previously

It is the purpose of this report to draw the attention of radiologists to the anterior and posterior spinal arteries In a series of several hundred vertebral angiographies, the anterior spinal artery has been identified by us in the lateral view in 50 % of cases, and in a much smaller proportion of cases we could identify the posterior spinal plexus In a recent series of vertebral angiographies performed via the brachial route reported by THOMAS et coll, the anterior spinal artery could be identified in 2 % of cases and KRAYENBUHL & YASARGIL (1957) identified these vessels positively in only three cases from their large series

Because of the constant location of the anterior spinal artery in the anterior

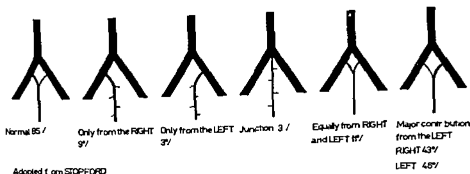


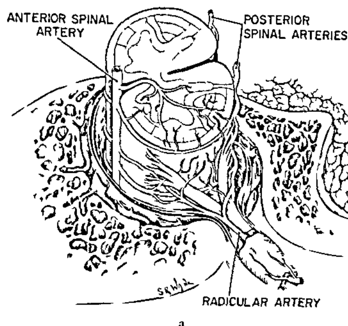
Fig 1 Variations in the origin of the anterior spinal artery

median raphe of the spinal cord demonstration of this artery angiographically allows an evaluation of the spinal cord position in relation to the vertebral canal The plexus of vessels derived from the anastomoses between the posterior spinal arteries delineates the posterior aspect of the cord Displacement of the spinal cord and these vessels may result from the patient s position (JIROUT 1959) but with the patient in the supine and the head and neck in the neutral position the anterior spinal artery lies within certain fixed limits Displacement of this artery may be caused by a pathologic process involving structures within the spinal canal

Another aspect of neuroradiologic significance relates to the possibility of the anterior spinal artery serving as a feeding vessel for an arterio venous malformation or a vascular tumor within the spinal canal Angiomas outlined by vertebral angiography have been reported by ZIEDSES DES PLANTES (1953) LINDGREN (1956) HOOK & LIDVALL (1958) and MORRIS (1960)

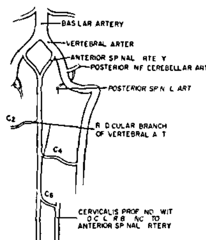
Also the anterior spinal artery may serve as a pathway for collateral circulation where there is occlusive disease involving the proximal portions of the vertebral arteries This has been recognized in the dog (DE LA TORRE et coll 1959) and we have seen this occur in an adult female

GILLILAN (1958) reviewing the anatomy of the spinal arteries credits ADAMKIEWICZ (1881) for the first extensive investigation of the blood vessels of the spinal cord This was followed by KADYI (1889), STOPFORD (1916) (see Fig 1) TUREEN (1938) SUH & ALEXANDER (1939) and HERREN & ALEXANDER (1939) GILLILAN studied the spinal cords and brains of 100 human fetuses ranging in age from six months fetal life to full term Corrosion studies of injected vessels were performed and observations made were confirmed in adult human material She observed no difference in appearance relative size or relationship between the arteries of fetuses and adults



a

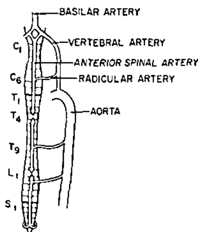
Fig 2 a) A schematic representation of the extrinsic vascular supply of the human spinal cord b) Segmental contribution to the anterior median spinal artery Radicular branches from the vertebral arteries at the cervical 2 and cervical 4 levels and a branch *from the cervical profunda at the* cervical 6 level c) The posterior spinal plexus d) The shaded area of the cord at T 4 and at L 1 represent the watershed area



b



c



d

Our studies involved radiography of the vessels of the cord injected with barium gelatin solutions We examined both the intact cord within the spinal canal and the cord after it had been removed We also used corrosion techniques on cords which had the vessels injected with a plastic resin

The anterior spinal artery extends the length of the spinal cord lying in close proximity to the anterior median fissure (Fig 2) The artery begins with the union of two vessels each coming off the distal vertebral arteries

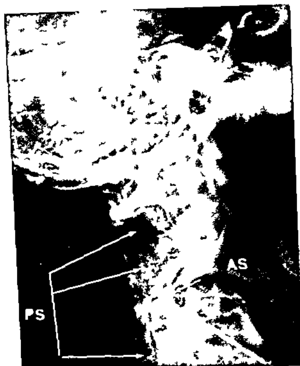


Fig 3 Lateral projection of a vertebral angiogram The spinal cord outlined by the anterior spinal artery (A S) and by the posterior spinal plexus (P S)

The vessels vary in size and not infrequently after joining the two vessels extend separately for a length of the cord lying next to one another Absence of one vessel has been seen in our corrosion specimens Only rarely are both absent (SPILLER 1908)

Segmental arteries contribute to the anterior median spinal artery and these branches are not infrequently seen during vertebral angiography The upper 3 to 5 cervical segments of the spinal cord are supplied by segmental branches of the cervical portion of the vertebral artery (GILLILAN 1958) The lower cervical region is supplied by various branches of the subclavian artery usually the ascending cervical or the profunda cervicalis (Fig 2 c)

The spinal cord down to the fourth thoracic (vertebral) segment is usually supplied by the anterior spinal artery the segmental branches from the vertebral artery the branches of the ascending cervical artery and by a branch of the profunda cervicalis which enters the canal through the intervertebral foramen between the 7th cervical and 1st thoracic vertebrae Below this level



Fig. 4. A lateral vertebral angiogram (a) demonstrating the anterior spinal artery which identifies the anterior margin of the spinal cord and corresponds with the cord outlined in a subsequent encephalogram (b) on the same patient.

the cord is supplied by branches from the aorta (Fig. 2 c). The territory between these two supply areas (referred to as a "watershed area") is relatively less vascularized and suffers most with impaired circulation (LAZORTHES 1958).

The anterior spinal artery is variable in width throughout its extent. It is usually well defined in the cervical region and gradually tapers from its origin towards the thoracic region, where it becomes hardly recognizable. The vessel may undulate from side to side looping towards the medullary arteries as they anastomose with it, or the anterior medullary arteries may bifurcate sending one limb up and one limb down.

The segmental arteries, from which the medullary arteries arise also supply the bone and dura. At the intervertebral foramen the vessel divides into an anterior radicular root and a posterior radicular root. These supply the corresponding nerve roots and disappear in these structures. Occasionally the posterior radicular artery extends into the spinal cord and supplies the posterior pial plexus (Fig. 3). Only at certain levels is there a second anterior or posterior branch of the radicular artery which joins the anterior or posterior spinal artery.

The intrinsic supply of the cord is by way of the anterior spinal artery the posterior spinal arteries and the fine network connecting them Short arterial stems arise from the anterior spinal artery and penetrate the median fissure to supply the central portion of the cord The more peripheral part is supplied by the vessels passing around the cord (Fig 2)

The posterior spinal arteries are in fact one posterior plexiform channel, running longitudinally and lying on the dorsolateral aspect of the spinal cord (Figs 2c and 3) The upper ends of these vessels originate as branches from the intracranial portions of the vertebral arteries They are distinct single vessels only at their origin and later become a network of anastomotic channels supplied by the posterior arteries arising from the radicular arteries The posterior spinal channels are joined at intervals by the posterior medullary arteries (about six to eight in number)

Many of the vessels making up the extrinsic supply to the cervical and upper thoracic cord may be identified during vertebral angiography (Fig 3)

Material and results

One hundred of our most recent vertebral angiographies performed by direct puncture were selected for this study In 50 % of these, the anterior spinal artery could be recognized in the lateral projection Rarely could it be recognized in the AP projection although a subtraction technique might help here In 4 % the posterior spinal plexus could be identified (Fig 3) In a small proportion of cases we were able to identify the segmental branches supplying the anterior spinal artery Two measurements were made 1) the width of the spinal canal at C2 and 2) the distance between the anterior spinal artery and the dorsal aspect of the body of the axis

The result may be summarized as follows A total of 100 vertebral angiographies (direct puncture) were studied The anterior spinal artery was identified in 51 cases and was not identified in 49 cases The posterior spinal plexus was identified in 4 cases (all had anterior spinals) The range of canal diameters at C2 was 1 6 to 2 4 cm and the range of the distance of the anterior spinal artery from the dorsal aspect of the body of C2 was 0 1 to 0 9 cm The average distance of the anterior spinal artery from the dorsal aspect of the body of C2 was 0 3 cm These measurements reflect the position of the anterior aspect of the spinal cord within the spinal canal in patients in the supine position with the head and neck in the neutral position A deviation from the average measurement must be great in order to be pathologic for there is a wide range of normality

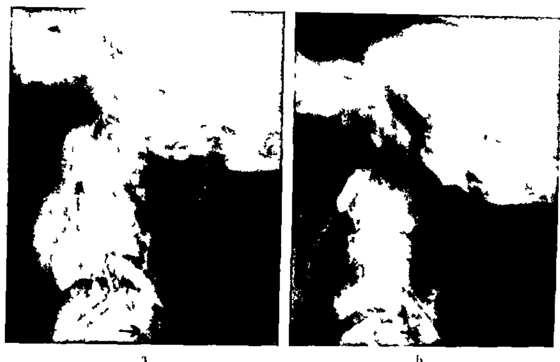


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Acknowledgement

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SUMMARY

The anterior spinal artery can be identified in 50 % of vertebral angiographies performed by direct puncture It can serve as a pathway for collateral circulation when the vertebral arteries proximally are involved by occlusive disease and it may feed a vascular pathologic process, this can be recognized angiographically Measurement of the distance of the anterior spinal artery from the back of C2 may be used in evaluation of displacement *of the spinal* cord, but caution must be exercised for the range of normal variation is great The posterior spinal plexus may be identified demonstrating the precise position of the posterior aspect of the cord and thus the size of the upper cervical spinal cord The segmental branches although frequent findings at post mortem are only occasionally outlined in vivo during vertebral angiography

ZUSAMMENFASSUNG

Die Art spinalis ant kann mittels Angiographie der Art vertebralis in 50 % der Fälle identifiziert werden Sie kann als Weg für die Kollateralzirkulation dienen wenn die Vertebralarterien proximal verschlossen sind und sie kann auch einen pathologischen Prozess mit Blut versorgen Dies kann angiographisch nachgewiesen werden Die Messung des Abstandes der Art spinalis ant zum dorsalen Teil von C2 kann für die Untersuchung von Verlagerungen des Rückenmarks diagnostisch ausgewertet werden wobei jedoch wegen der normalerweise vorkommenden grossen Variation der Masse Vorsicht in der Beurteilung geboten ist Durch den Nachweis des Plexus spinalis posterior kann die genaue Lage der hinteren Begrenzung des Rückenmarks und somit die Ausdehnung des oberen Cervikalmarks dargestellt werden Obwohl die segmentalen Äste post mortem häufig gefunden werden kommen sie bei der *vertebralen Angiographie in vivo nur gelegentlich zur Darstellung*

RÉSUMÉ

On peut identifier l'artère spinale antérieure dans 50 % des angiographies vertébrales faites par ponction directe Elle peut servir à la circulation collatérale quand les artères vertébrales sont obstruées dans leur partie proximale et elle peut irriguer un processus pathologique vasculaire ceci est visible sur l'angiographie La mesure de la distance de l'artère spinale antérieure à la face postérieure de C 2 peut servir à apprécier le déplacement de la moelle, mais cette appréciation doit être prudente car les variations normales sont grandes Le plexus spinal postérieur peut être identifié situant avec précision la face postérieure de la moelle et permettant ainsi de mesurer le diamètre de la moelle cervicale supérieure Les branches segmentaires bien que souvent visibles post mortem ne sont que rarement visibles sur les angiographies vertébrales in vivo

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FROM THE CLINICA MEDICA UNIVERSITARIA (PROF. A. PEDRO PONS) DE LA FACULTAD DE MEDICINA DE BARCELONA, SPAIN

RADIOLOGIC ASPECTS OF SPINAL BRUCELLOSIS

by

J. SOLÉ LLENAS, J. ROTÉS QUEROL and M. DALMAU CIRIA

Bone and nervous manifestations, particularly those affecting the spinal column, are frequently observed in brucellosis. There are two types of lesions: 1) osteoarticular lesions (spondylitis and sacroiliitis), and 2) those affecting the intradural nervous structures (meningomyelitis and meningoradiculitis, with or without constrictive arachnoiditis).

The roentgen diagnosis is made by conventional radiography as well as by myelography.

Material. The total material consists of 192 cases during the period 1927—1963, in 156 of which a variable degree of involvement of the spinal column was observed; from the radiologic point of view this group includes 92 cases of spondylitis, 31 cases of sacroiliitis and 9 cases of intradural changes, manifested radiologically by arachnoiditis.

The diagnosis of brucellosis was based on epidemiologic studies and agglutination tests and confirmed in some cases by blood and cerebrospinal fluid cultures.

Spondylitis

Spondylitis, the most common sign of osteoarticular brucellosis, occurred in 92 cases (58.9 %). There was a marked predominance of males over females



Fig 1 Epiphysitis of the anterosuperior margin of L4



Fig 2 Flattening of D7 with decrease in the height of the anterior border



Fig 3 Cervical lesions of the so-called soft type with extensive destruction of bone and disks and spinal deformity

with a higher incidence over the age of 50 Spondylitis is the rule in patients with brucellosis over the age of 55

The lumbar region was most frequently affected (74 cases) Several vertebrae usually non adjacent were involved a polytopic distribution in contrast to the monotopic distribution typical of Pott s disease Two or three vertebral bodies L4 L3 and L5 in that order of frequency are generally affected Lesions in the dorsal region are confined to D11 and D12 The cervical region is seldom the site of changes The lesions seem to have a tendency to be superimposed upon traumatic and osteoarthritic lesions and congenital malformations

Changes may be absent in the so called abortive form of the disease They usually appear however as a focal lesion of the vertebral body The trabecular structure appears blurred and irregular with osteoporotic zones alternating with increased bone density In a later phase the lesion is more evident in the anterosuperior part of the vertebral body described as epiphysitis by PEDRO PONS (1929) The osteitic focus appears as a small loss of substance mostly localized to the same region (Fig 1) Marked destructive lesions and even detachment of the epiphyses may finally occur

Although some changes in the shape of the vertebral body may be seen this is not the rule However in some cases a flattening with a decrease in height

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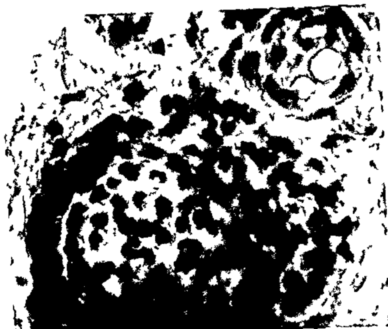


Fig 5 Brucellar granuloma Typical round mononuclear cells rich in eosinophilic protoplasm and with large nuclei

Histology revealed that brucellar spondylitis consists of interstitial edema and infiltration of small and large monuclear cells through the cancellous bone, in some parts giving rise to granulomas The most characteristic sign is the presence of mononuclear round cells with considerable eosinophilic protoplasm and large nuclei (Lowbeer's cells) (Fig 5) In some areas the granulation tissue produces partial or total reabsorption of the bone trabeculae (zone of roentgen osteoporosis)

Nodules with a focus of necrosis may appear in the granulation tissue These nodules may become calcified and even break down in 3 or 4 months At the same time a reparative process starts as a proliferation of the connective tissue around the lesion with the formation of new trabeculae within the bone in the periosteal region and in the space between the disk and the ligaments The formation of new bone would appear to be due to mechanical influences and to be completely independent of the inflammatory process

Complication of spondylitis A frequent complication is the appearance of an abscess This seldom produces any clinical manifestation and is generally discovered during the radiologic examination It was present in 12 of the



Fig 4 Brucellar spondylitis of L2 and L3 with osteophytic reaction and narrowing of the intervertebral space

of the anterior aspect of a dorsal vertebral body may be observed, the body may collapse as in tuberculous spondylitis (Fig 2) A narrowing of the disk space was evident in 90 % of the cases and in some was the only sign of brucellar spondylitis The disk lesions were generally associated with other bone lesions (Figs 1 and 4)

It is not unusual to observe geodic formations in the cancellous bone of the vertebral bodies near the intervertebral disk These may be confused with Schmorl's nodes but are larger and more irregular Lesions of the interapophyseal joints, with blurring of the articular facets, associated with subchondral osteoporosis, were present in one case

Osteophytes often appear in advanced cases close to the osteolitic focus (Fig 4) They appear generally in cases with marked narrowing of the disk space and displacement of the vertebrae These lesions probably represent a nonspecific bone reaction to the direct brucellar destruction (ROTÉS QUEROL)

Pathology A pathologic study was performed by PEDRO BOTET, CISCAR & J ROTÉS QUEROL in 4 cases They stated that the destructive lesions are produced by granulation tissue that starts from the bone marrow, destroys the surrounding bone trabeculae and invades the disk through the geodic formations of the cancellous bone The destruction of the intervertebral disk gives rise to the formation of osteophytes, these may be considered as signs of a reconstructive phenomenon

trum in a cavity The widening of the joint space may be regular or irregular and the margins of the joint may be undulating The articular facets may be poorly defined irregular and even completely fragmented Changes in density of the periarticular bone are also frequent

Involvement of the intradural structures

Neurotropism is one of the characteristics of brucellosis Involvement of the intradural nervous structures and their sheaths may take place by propagation of adjacent spondylitis or by independent hematogenous invasion through the meninges the latter being the more frequent

The meningeal participation is a constant phenomenon manifested in most cases by adhesive arachnoiditis associated with a myelo or radicular syndrome depending on the level The lesions are produced by a hyperplastic prolifera tion of the meninges or by the formation of a true cyst Out of 30 cases with myeloradicular manifestations only 9 had arachnoidal lesions on myelo graphy

A longer version of this paper was read at the Symposium

SUMMARY

The characteristic radiologic signs of brucellar spondylitis and sacroiliitis and some less common evidence of arachnoiditis are described with reference to 156 of a total material of 192 cases of brucellosis

ZUSAMMENFASSUNG

Die charakteristischen Röntgenveränderungen der Wirbelsäule und der Sakro-iliakal Gelenke sowie ungewöhnlichere Zeichen einer Arachnoiditis werden bei der Brucellose (Maltafieber) anhand von 156 Fällen von einer Gesamtzahl von 192 Fällen beschrieben

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Description des signes radiologiques caractéristiques des localisations rachidiennes et sacro-iliaques de la brucellose et de signes plus rares d arachnoïdite d après 156 cas sur un total de 192 cas de brucellose

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Fig 6 Brucellar sacroiliitis Irregular widening of the joint space with blurring of its outline on the left side

present cases An abscess in the lumbar region appears as a prominence of the psoas shadow and is usually bilateral A dorsal abscess is generally unilateral and appears mainly in the lower part of the region between the insertions of the diaphragm and the spine A cervical abscess usually lies in front of the spine and between it and the trachea

Another complication of spondylitis is its propagation towards the vertebral canal, affecting the intradural nervous structures (spinal cord and nerve roots) This problem will be examined later

Sacroiliitis

Sacroiliitis occurred in 31 cases of the material and tended to resolve spontaneously, without sequelae in 2 or 3 months

Males were affected twice as often as females The incidence was higher among younger patients, possibly due to the complete loss of mobility of the sacroiliac joint after the age of 50 The lesions are generally unilateral

Sacroiliitis is characterized by its early appearance, 10 or 15 days after the onset of clinical signs, in contrast to tuberculous lesions The initial lesion consists of an irregular diastasis of the articular space with blurring of the edges (Fig 6) The diastasis may reach a width of 0 5 to 1 cm and even 2 cm and a fragment of cancellous bone which has been called an 'island' by ROTÉS QUEROL, may appear between the articular facets and suggest a seques

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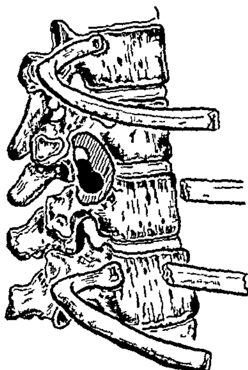


Fig 1 Diagram of lateral approach operation for protruded thoracic disc (Kind permission of A Hulme F R C S)

T6
7
8
9
10
11
T12

2
2
1
2
3

Fig 2 Levels affected in the 10 cases reported

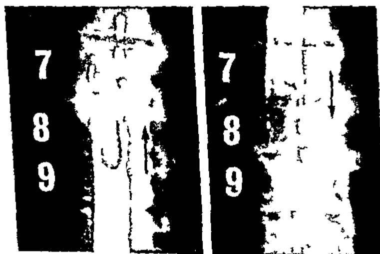


Fig 3 Case 1 Myelography Elongated oval defect from T7–T9

FROM FRENCHAY HOSPITAL, BRISTOL, ENGLAND

MYELOGRAPHY IN DORSAL DISC PROTRUSION

by

J. L. G. THOMSON

Thoracic disc protrusion is an uncommon lesion with little more than one hundred cases recorded in the literature, but as it is amenable to surgery it is important that it should be recognised.

It does seem, however, that for a benign compressive lesion of the cord the results of surgical treatment, as recorded, are often disappointing. Thus in LOGUE's (1952) series of eleven cases, six were better following operation and five were worse. In 1960 TOVI & STRANG reported improvement in four out of a series of fourteen cases. It may be of some relevance that the operation generally employed is the standard laminectomy procedure, for this does of necessity entail some handling of the spinal cord.

In 1960 HULME described a lateral approach operation (Fig. 1) involving excision of the heads of two ribs, and widening of the appropriate intervertebral foramen (shaded area) to allow undercutting of the offending disc (shown black) and removal from in front. By this method the dura remains unopened and the spinal cord very little disturbed so that neurological trauma is at a minimum. In the Neurosurgical Unit at Bristol, England, there have been thirteen cases of thoracic disc protrusion in the last nine years, of which ten cases have been confirmed surgically. As the other three cases were treated medically, and are therefore unconfirmed, they will not be referred to again.



Fig 5 Case 2 myelography Almost complete obstruction to the upward flow of myodil

paper the conventional film and the tomographic findings are grouped together

Myelography is performed with the patient prone using 5 ml of myodil, the flow being screened and routine films taken Should there be incomplete obstruction to the flow of myodil in the dorsal region great care is taken to exclude any other lesion higher up It is also a basic principle that the myelographic defect should correspond with the clinical syndrome

According to the myelographic findings there was complete obstruction in three cases almost complete obstruction in one a central filling defect in five and a lateral J shaped defect in one When the obstruction was complete or almost complete the shape of the myodil indicated extrathecal compression with deflection away from the back of the vertebral bodies in the lateral view mostly adjacent to the disc space The oval filling defect varied from 2 cm to 4 cm in length the smaller defect corresponding quite clearly with the disc space The rate of myodil flow was unaffected by the small lesion, hence the necessity for careful screening and routine films Again in the lateral view there was some deflection away from the vertebral bodies at the disc space and in one case a double profile was evident where some of the myodil deflected by the disc contrasted with myodil flowing around its side With the



Fig 1 Case 1 Tomography Large osteophytes revealed

Of the ten cases operated, eight were approached laterally as outlined above, seven of these recovering well and the other one showing continued improvement The other two cases had the standard laminectomy operation one is recovering well and the other remaining unimproved

The objects of this paper therefore are firstly to draw attention to this particular operation, and secondly to review the radiological appearances of dorsal disc protrusion

In our group there were six females with an average age of forty seven years, and four males with an average age of thirty eight years The levels are indicated in Fig 2, all protrusions being single ones, as is usually the case

Minor trauma may initiate symptoms, and five of our ten cases recalled antecedent incidents such as twisting movement, stretching or lifting heavy weights Root pain may predominate if the protrusion is mainly lateral, but otherwise the symptoms resemble any other cord compressive lesion and the more central the protrusion the more motor and sensory loss there will be

The cerebrospinal fluid findings are not typical and the diagnosis rests on the radiological findings

Our routine in cases with spinal cord compression is to follow conventional films, where necessary, by myelography and then to proceed to lateral tomography should dorsal disc protrusion be suspected For the purposes of this



Fig 7 Case 3 *Left views* Myelography Upward flow of myodil blocked below the disc space *Right view* Tomography Calcified disc material in the spinal canal and calcification in the disc space

Case 3 A 42 year old man had a sudden onset of pain in the back on lifting and within *three weeks had* become paraparetic The myodil was completely blocked some distance below the disc space (Fig 7 left views) Lateral tomography showed calcification in the disc space and protruded disc material in the canal (Fig 7 right view)



Fig 8 Case 4 *Left views* Myelography Small shelf demonstrated with myodil flowing up and down *Right view* Tomography Flecks of calcium in the spinal canal Calcification in the disc space

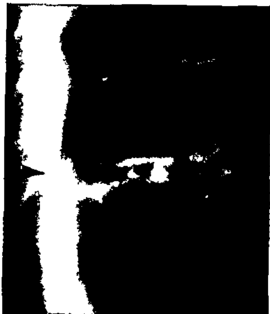


Fig 6 Case 2 Tomography Calcification in the disc space with small posterior osteophytes

patient supine the defect was usually less clear cut, confirming that the lesion was anteriorly placed in the spinal canal

With myelographic findings such as these, suggestive of protruded thoracic disc, further information was obtained by lateral tomography of the spine This examination revealed calcification in the disc space and posterior osteophytes in four cases, calcification in the disc space as well as posterior calcification in four cases, and a normal disc space in two cases This information was considered diagnostic in eight cases In the two cases where no abnormality could be demonstrated the diagnosis could be made at myelography, where the backward deflection of the myodil at a disc space was considered characteristic In one case there was an incidental finding of calcification in an adjacent disc space and in four cases there was incidental Scheuermann s disease

Examples

Case 1 A 32 year old female stretched in bed one morning and was seized by a sudden girdle pain She became completely paraplegic within the next three hours Myelography the same day (Fig 3) showed an elongated oval defect centrally from T7 to T9 Lateral tomography (Fig 4) showed calcification in the disc space and large osteophytes protruding into the spinal canal

Case 2 A 59 year old female with gradual onset of numbness of the legs over six weeks Myelography (Fig 5) showed an almost complete obstruction to myodil The lateral tomogram (Fig 6) showed calcification in the disc space with small osteophytes posteriorly

FROM THE DIVISION OF NEUROLOGY, DEPARTMENT OF MEDICINE, WESTERN RESERVE UNIVERSITY SCHOOL OF MEDICINE, AND UNIVERSITY HOSPITALS OF CLEVELAND USA

CAUDA EQUINA DAMAGE AFTER THORIUM DIOXIDE MYELOGRAPHY

by

HOWARD J TUCKER WILLIAM A SIBLEY and LOWELL W LAPHAM

Thorotrast a colloidal solution of thorium dioxide a radioactive material with a long half life (about 14 billion years) was widely used for myelography from about 1938 until 1945 (15 16 17, 18) Its use was curtailed because of concern about potential tissue damage and neoplasia (1 2 9 10, 11 12 13 14) and because more satisfactory contrast media became available

Within the past six years we have examined three patients with severe cauda equina damage beginning five to eighteen years after Thorotrast myelography A fourth patient with an identical clinical picture is presumed to have had Thorotrast myelography but actual confirmation is lacking All patients had paralysis of urinary and rectal sphincters diminished or absent tendon reflexes in the lower extremities and saddle analgesia In some cases there was significant weakness and loss of proprioceptive sensibility in the legs We know of no other reports of this complication except for a recent description of three similar cases by MALTBY (13) The occurrence of this late complication is probably due to the radioactivity of residual contrast media and is of special interest because of the long interval between myelography and the first symptom of neural damage

Case 4 A 50 year old man twisted his back and developed numbness of his feet At myelography a shelf could be demonstrated with the myodil flowing up and down (Fig 8 left views) The lateral tomogram showed calcification in the disc space and flecks of calcium in the spinal canal (Fig 8 right view) There is incidental Scheuermann s disease

Case 5 A man of 29 with a one month's story of spinal cord compression showed a complete block to the flow of myodil following cisternal myelography Tomography failed to show any abnormal calcification or osteophyte formation but a large disc protrusion was confirmed at operation

Acknowledgement

Presentation of the paper at the Congress was assisted by the award of a Wellcome Research Travel Grant for which my sincere thanks are gratefully recorded

SUMMARY

The findings at myelography in cases of dorsal disc protrusion are summarised in 10 cases that came to surgery Lateral tomography of the spine gave considerable assistance in the confirmation of the diagnosis Attention is drawn to the lateral approach operation for the removal of a protruded dorsal disc

ZUSAMMENFASSUNG

Die myelographischen Befunde von 10 Fallen von dorsaler Diskusprotrusion die zur Operation kamen wurden zusammengefasst Die laterale Tomographie des Ruckens war fur die Stellung der Diagnose von grosser Bedeutung Zur Entfernung eines protrudierten dorsalen Diskus wird auf den lateralen Operationsweg aufmerksam gemacht

RÉSUMÉ

Description des signes myélographiques de la protrusion discale dorsale d après 10 cas opérés La tomographie de profil du rachis a beaucoup facilité la confirmation du diagnostic L auteur attire l attention sur l abord chirurgical latéral pour l exérese d une protrusion discale dorsale

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Case material

Case 1 A 42 year old woman was seen in 1959 because of increasing constipation for 7 years and progressive incontinence of urine for 3 months In 1942 at age 26 Thorotrast myelography had been performed at another hospital and had revealed a definite large herniated intervertebral disc on the left side between L 5 and S 1 After a laminectomy she was entirely free of her previous complaint of left sciatica and remained asymptomatic until 1958

Examination in 1959 showed a normal gait except for a limp favoring the left leg She could not walk well on her heels and direct muscle testing confirmed mild weakness of the dorsiflexors of the feet bilaterally Muscle strength in the lower extremities was otherwise intact Straight leg raising was restricted to 45 on the right because of pain in the right buttock The right knee jerk was depressed compared to the left ankle reflexes were absent bilaterally Plantar responses were flexor There was extensive anesthesia in a saddle distribution bilaterally, and anesthesia posteriorly in the right thigh and calf Vibratory sensation was diminished in the right foot but position sense was preserved Occasional fasciculations were noted in the right buttock Rectal sphincter tone was definitely decreased

Cystoscopy showed an atonic bladder with a capacity of 500 ml and a 350 ml volume of residual urine Roentgenograms of the spine showed residual Thorotrast largely concentrated in the sacral spinal canal but present in lesser amounts as high as L 1 (Fig 1) Lumbar puncture revealed clear fluid with normal pressures and dynamics but cerebrospinal fluid protein was 115 mg % Myelography with Pantopaque in 1959 showed a free flow of contrast medium from the sacral cul de sac to the mid thoracic region

In 1964 examination because of progressive difficulty in walking during the preceding 5 years showed more extensive weakness involving the dorsiflexors of the feet and gastrocnemius gluteus maximus and hamstring muscle groups bilaterally The right knee jerk was now absent but the left knee jerk was still present Ankle jerks remained absent with flexor plantar responses Sensory deficit was similar to that recorded in 1959 but the rectal sphincter was now patulous There was complete urinary incontinence

Case 2 This 57 year old man was first examined 1961 because of progressive urinary and fecal incontinence for 18 months He had been treated at another hospital in 1941 for recurrent right sciatica and low back pain of many years duration Thorotrast myelography in 1941 was said to be normal but a herniated intervertebral disc had been removed at L 4 5 He was then asymptomatic until the onset of the present complaints

Examination in 1961 showed mild weakness of dorsiflexion of the left foot but good muscle strength was present in all other muscle groups including gluteal and hamstring muscles Deep tendon reflexes were normally active except for an absent left ankle reflex Sensory examination revealed marked loss of pain and touch sensation in a saddle distribution over the buttocks bilaterally corresponding to the second sacral to fifth sacral dermatomes The rectal sphincter was patulous

Roentgenograms of the lumbosacral spine showed evidence of an old laminectomy and fusion and the dural cul de sac was outlined by a rim of contrast medium (Fig 1) Lumbar puncture revealed clear fluid with open manometrics and a cerebrospinal fluid protein value of 49 mg per 100 ml Myelography with Pantopaque was normal

Because of fecal incontinence a colostomy was performed in 1962 and he found it necessary to wear a urinal No further leg weakness developed and there has been no change in his neurological deficit during the past 3 years

Case 3 A 65 year old housewife was examined by us in 1959 with a complaint of constipa



Fig 1 Conventional roentgenograms of lumbosacral spines of Cases 1 2 3 and 4 taken 17 20 18 and 0 years respectively after Thorotrast myelography

tion and occasional urinary and fecal incontinence of 9 years duration and progressive leg weakness for 5 years

In 1942 at age 49 she had had low back discomfort with a normal neurological examination Thorotrast myelography elsewhere in 1943 revealed nothing of interest and at the time of discharge she was asymptomatic In 1948 she developed urinary retention and a bladder neck resection was done Examination in 1954 revealed a mild paraparesis and both patellar and ankle reflexes were absent Plantar responses were flexor The anal sphincter was patulous and there was a definite saddle analgesia Spinal fluid examination showed an initial pressure of 103 mm of cerebrospinal fluid normal dynamics and a total protein value of 26 mg per 100 ml The colloidal gold reaction was normal By 1957 14 years after Thorotrast myelography the patient was no longer able to walk and used a wheelchair

In 1958 she was admitted to University Hospitals for evaluation with moderate weakness of both lower extremities more severe on the left and with greater involvement distally No fasciculations were seen Deep tendon reflexes were normal in the upper extremities but absent at the knees and ankles There was hypalgesia and absent vibratory sensation below the knees Position sense was markedly decreased in both feet more severely so on the left Saddle hypalgesia was present and the anus was patulous Roentgenograms of the thoracic spine were normal but throughout the lumbar spinal canal there was residual Thorotrast (Fig 1) Myelography with Pantopaque showed free flow of the medium from the sacral cul-de sac to the foramen magnum The cerebrospinal fluid protein was 88 mg per 100 ml and there were no white cells in the fluid Her weakness progressed and she died suddenly in 1961

Case 4 A 56 year-old retired laborer was admitted in 1961 because of rectal incontinence for 2 months In 1953 presumably for symptoms of prostatism he underwent transurethral resection and suprapubic prostatectomy Since that time there had been total urinary incontinence and impotence Since 1949 he had suffered from progressive weakness of the legs

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each of our patients This was considered especially important because of the progressive course in all patients and because three of the patients had elevated cerebrospinal fluid protein values Pantopaque myelography was interpreted as normal in all four cases in spite of biopsy proven arachnoiditis in one of the patients and presumed adhesive arachnoiditis in the other three It is evident, therefore that the outline of the subarachnoid space as demonstrated by myelography with Pantopaque may not show the classical radiological picture of arachnoiditis though significant arachnoiditis is present

It is probable that the cases reviewed here reflect only a small per cent of those developing neurological damage following Thorotrast myelography Because of the time interval between injection of Thorotrast and the onset of symptoms the syndrome of thorium induced cauda equina damage may go unrecognized unless a careful history is elicited The presence of the typical roentgenograms produced by Thorotrast retained in the lumbosacral canal should alert the examiner to this diagnosis

SUMMARY

Four patients developed signs of progressive damage to the cauda equina many years after thorium dioxide myelography The number of years elapsing between myelography and first symptoms of neural damage was inversely proportional to the amount of retained Thorotrast in the lumbosacral spinal canal The clinical localization and extent of neurologic damage correlated with the position and estimated volume of residual contrast media In all patients myelography with Pantopaque was normal after cauda equina damage had developed

ZUSAMMENFASSUNG

Vier Patienten entwickelten viele Jahre nach einer Thoriumdioxid Myelographie Anzeichen einer progressiven Schädigung der Cauda equina Das zeitliche Intervall zwischen Myelographie und den ersten Nervenstörungen ist umgekehrt proportional zur Menge des im lumbosacralen Spinalkanales retinierten Thorotrasts Die klinische Lokalisierung und das Ausmass des Nervenschadens korrespondierte mit der Lage und einer bestimmten Menge retinierten Kontrastmittels Bei allen Patienten bei denen sich einen Cauda equina Schaden entwickelt hatte war die Myelographie mit Pantopaque normal

RÉSUMÉ

Quatre malades ont présenté des signes de lésion progressive de la queue de cheval de nombreuses années après une myélographie au dioxyde de thorium Le nombre d années écoulé entre la myélographie et les premiers symptomes de trouble neurologique est inversement proportionnel a la quantité de Thorotrast restant dans le canal rachidien lombo-sacré La localisation clinique et l étendue des signes neurologiques concorde avec la position et le volume du moyen de contraste résiduel Chez tous ces malades la myélographie au Pantopaque faite après le début des lésions de la queue de cheval a été normale



Fig. 2. Case 4. *Left view*. Myelogram. No significant distortion of the column of contrast medium in spite of biopsy proven arachnoiditis. *Right views*. Surgical biopsy of the arachnoid in the lumbosacral area. Deposits of brown granular material within dense connective tissue, presumably Thorotrast. Hematoxylin eosin × 200 (top), × 720 (bottom).

which was more severe in the left leg. For the 18 months prior to his first examination by us in 1961 he had been confined to a wheelchair. Myelography had been performed in the early 1940's for obscure reasons, and in 1947 roentgenograms of the lumbar spine at another hospital revealed contrast material outlining the entire lower spinal canal (Fig. 1).

On neurological examination paresis of the entire left lower extremity was noted. Except for marked weakness of the dorsiflexors of the toes and hamstring muscles, there was good strength in all muscle groups of the right lower limb. Gluteal strength was fair on both sides. Straight leg raising was limited bilaterally at 45 by pain in the buttocks. Knee and ankle jerks were absent. Anal and bulbocavernosus reflexes were absent and the anal sphincter was patulous. There was moderate atrophy of both lower extremities. No fasciculations were seen. Hypalgesia was present in the L 3 dermatome and analgesia was found from L 4 through

S-5 on the left and from S 2 through S 5 on the right Position sense was lost in the left foot and vibratory sense was absent below the knees bilaterally

A lumbar puncture revealed open manometrics and a cerebrospinal fluid protein of 96 mg per 100 ml Myelography with Pantopaque in January 1961 showed nothing abnormal (Fig 2) No untoward reactions occurred after myelography During the next 8 months there was progression of his symptoms and repeat examinations showed hypalgesia as high as L-1 on the left side In August 1961 a laminectomy was performed The ligamentum flavum was markedly adherent to the dura at the T 12 vertebral level the dura was a dull yellow color and was markedly thickened The arachnoid was greatly thickened and adherent to the nerve roots and the conus medullaris

Microscopic examination of the ligamentum flavum showed excessive connective tissue with calcification the arachnoid was fibrotic and hyalinized Within the fragments of fibrosis several areas of brownish globular material were seen which were regarded as residual Thorotrast (Fig 2) (We have been unable to locate old hospital records to confirm that the contrast material at the initial myelography was thorium dioxide We have presumed this to be Thorotrast because the residual contrast material on the roentgenograms had the same appearances as in the cases known to have had myelographies with Thorotrast Further the brown deposits in the biopsy specimen resemble the Thorotrast demonstrated by others in soft tissue (12 and is unlike the microscopic picture of either Lipiodol or Pantopaque Lastly the myelography was done during the few years in which Thorotrast myelography enjoyed a brief period of popularity in this area)

The patient showed no improvement and was discharged to the care of his family He died suddenly in January 1963

Discussion

The four patients presented here and the three patients described by MALTBY (13) are similar with respect to certain historical features and neurological findings All patients were examined by *Thorotrast myelography in the early* 1940 s for clarification of acute low back pain or sciatica Regardless of the nature of the original illness the pain which prompted Thorotrast myelography subsided in all patients either spontaneously or after operation Then after a lengthy symptom free interval (range 5 to 15 years) each patient developed a neurological disturbance

The clinical features of this post thorium dioxide myelography syndrome in these 7 patients *are outlined* below

Symptoms and signs	*Number of patients*
Urinary incontinence	
Weakness of legs	7
Absent ankle reflex	7
Sensory loss (including three patients reported by MALTBY)	7
Rectal incontinence	6
Absent patella reflex	6
Pain in legs	4
Spasticity	4
Babinski sign	0
	0

Thus it can be seen that the most common symptoms and signs are urinary and fecal incontinence, absent ankle reflexes and weakness of the legs In five of the seven cases urinary incontinence was the initial symptom The extent of motor and sensory loss is variable from case to case and appeared to correlate with the amount and location of residual Thorotrast in our four patients The latency between Thorotrast myelography and the beginning of the post myelography cauda equina syndrome was shorter in the patient having the largest amount of retained contrast media In Case 3, only five years elapsed between myelography and the onset of urinary incontinence This patient had a greater amount of retained Thorotrast than did the other three patients (Fig 1, No 3) All of our patients had saddle analgesia, again reflecting major damage in the lower sacral segments due to a greater concentration of retained thorium in the sacral cul de sac Although this distribution of sensory loss is not mentioned by MALTBY it seems probable that it was present in his patients since they, too, had urinary and fecal incontinence and other evidence of cauda equina damage We believe that the neurological deficit in all of these cases is due to damage to the cauda equina secondary to radiation effect

Both clinical and experimental evidence has shown that the central nervous system is more radiosensitive than the peripheral nerve fibers (6, 7, 8) However, it is likely that the spinal cord is spared in our cases following Thorotrast myelography because of the distance of the retained contrast medium from the spinal cord in some of the cases and because of the low penetrating properties of alpha ray activity It is known that 'chemically pure' thorium dioxide may display increasing radioactivity for several years as disintegration products accumulate (1, 4), and that the alpha ray emitting properties of thorium are the most important emanation causing direct damage to tissue However, the penetrating properties of alpha particles are estimated at only one millimeter (4) Therefore, the most severe disruption of function should occur in areas of highest concentration of residual Thorotrast, probably in the nerve roots as they emerge from the spinal canal MALTBY (13) referred to this post thorium dioxide syndrome as a myelopathy Since the spinal cord is probably not involved, or at least is not the major site of damage, the term myelopathy seems misleading

Direct confirmation of the presumption that major damage occurs in the nerve roots of the cauda equina must await careful postmortem studies However, that an intense reactive fibrosis occurs in the meninges in the area of retained thorium seems quite definite in view of the biopsy findings in Case 4

Because Thorotrast is capable of inducing neoplasia, it seemed important to rule out the presence of an extramedullary tumor in the spinal canal in

each of our patients This was considered especially important because of the progressive course in all patients and because three of the patients had elevated cerebrospinal fluid protein values Pantopaque myelography was interpreted as normal in all four cases in spite of biopsy proven arachnoiditis in one of the patients and presumed adhesive arachnoiditis in the other three It is evident therefore that the outline of the subarachnoid space as demonstrated by myelography with Pantopaque may not show the classical radiological picture of arachnoiditis though significant arachnoiditis is present

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Reflexions apres le VIIeme Symposium

Les procedés physiques sortent le neuroradiologiste de son monde anatomique directement accessible et l introduisent dans un monde de signes indirects neurophysiologiques ou physiques Pour la premiere fois dans l histoire de nos Symposia de nombreuses communications se trouvent consacrees a des techniques non radiographiques Mais le deroulement du Symposium a montre que la tomographie a ultra sons B nous ramene à l anatomie Je pense que notre President a bien fait de nous inviter vers des nouvelles frontieres pour nous familiariser avec des techniques physiques «Jusqu a present» dit Jean ROSTAND «on n a jamais fait rien de mieux dans la nature que le cerveau» permettez nous d ajouter — et rien de plus difficile a explorer!

Ces techniques biophysiques sont ambulatoires et complementaires, elles interrogent le cerveau vivant et souffrant en termes differents en plus des rayons de Roentgen les rayons gamma ou infra rouges les vibrations infra ou ultra sonores les oscillations electromagnetiques sont mis en oeuvre dans l espoir de completer le manque d information d une methode par la reponse positive d une autre egalement pour parer a l erreur d un procede par la rectification d un autre

Dans l ouvrage de TAVERAS et WOOD Diagnostic Neuroradiology nos collegues distinguent la neuroroentgenologie de la neuroradiologie cette derniere comprend en plus des rayons de Roentgen un eventail de techniques se deployant du rayonnement gamma a l infra rouge des oscillations infra ou ultra sonores aux oscillations electromagnetiques

Precisons qu il ne parait nullement obligatoire que le neuroradiologue pratique avec ses mains toutes ces techniques il devient par contre indispensable pour lui de connaitre les examens complementaires leur signification ainsi que leur articulation avec l image neuroradiologique

Dans le cadre d une equipe de neurologie de neurochirurgie ou de neuroradiologie les techniques complementaires du systeme nerveux central doivent echoir aux specialistes competents la nature biophysique des techniques complementaires souligne l utilite considerable d un physicien a l interieur de l equipe l autonomie la dependance ou l independance de laboratoires ainsi specialises se developperont a la mesure des responsabilites exercees

Ne cherchons pas de formules prefabriquees car pour ce dernier aspect le facteur humain prendra toujours le dessus

H Fischgold